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**Ownership Structure and
Efficiency: An Incentive
Mechanism Approach**

by
Liang Zou

Reprinted from Journal of Comparative
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**Reprint Series
no. 127**



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Ownership Structure and Efficiency: An Incentive Mechanism Approach¹

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We compare efficiency implications of two team production models involving problems of team moral hazard and adverse selection. The models, formalized in a generalized principal/multiple-agent framework, differ only in the underlying ownership structures, one characterized by absentee ownership, the other by cooperative ownership. Explicit comparison of optimal contractual solutions suggests that, even if a firm is viewed as a nexus of complete contracts, the ownership structure of the firm matters for its economic efficiency. In this context, the cooperative firm can achieve first-best production efficiency, whereas the absentee-owner's firm cannot. Related issues are discussed throughout the paper. *J. Comp. Econom.*, September 1992, 16(3), pp. 399-431. University of Limburg, 6200 MD Maastricht, The Netherlands. © 1992 Academic Press, Inc.

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1. INTRODUCTION

In this paper we reconsider a frequently asked question: "Given a firm that is viewed as a nexus of contracts, does the location of ownership have any

¹ This paper grew from a chapter of my doctoral thesis written at CORE/IAG, University of Louvain-la-Neuve, and revised at CentER, Tilburg University, and at the University of Limburg. I am deeply grateful to Claude d'Aspremont and Maurice Marchand for their excellent supervision of my research, and to two anonymous referees of this Journal for very helpful comments and suggestions. Although the opinion and remaining errors are my own, I also thank Svend Albæk, Vicky Barham, Josef C. Brada, Eric van Damme, Mathias Dewatripont, Françoise Forges, Roger Guesnerie, Jean François Mertens, seminar participants at CentER, Tilburg University, University of Graz, University of Wien, the 6th World Congress of the Econometric Society in Barcelona, and the 5th Annual Congress of European Economic Association in Lisbon for helpful suggestions and discussions. Financial supports from ABOS and from CentER are also gratefully acknowledged.

impact on its economic efficiency?" A prevailing answer to this question, which we call the irrelevance hypothesis, is that insofar as the firm can be described as a comprehensive contract, where every contingency is thought of and built into the contract, ownership is irrelevant to the issue of efficiency. Location of ownership rights can only matter when it is impossible to write up such a comprehensive contract at the first date (see, e.g., Hart, 1988; Tirole, 1988). This observation explains the vast variety of extant approaches addressing issues of ownership and efficiency, which all mark a departure in one way or another from the complete and comprehensive contract. These include the incomplete contract approach (e.g., Grossman and Hart, 1986; Hart and Moore, 1988; Milgrom and Roberts, 1989), the behavioral approach (e.g., the references in Jensen and Meckling, 1979, footnote 6; the overview in Bonin and Putterman, 1987, pp. 5–8; Mcleod, 1987), the budget-breaking approach (e.g., Holmström, 1982; Macleod, 1988), and the fixed-form contract approach (e.g., Sen, 1966; Alchian and Demsetz, 1972; Stiglitz, 1974; Putterman and Skillman, 1988).²

However, the irrelevance hypothesis begs the important question of why the bargaining parties necessarily always arrive at the same level of production efficiency in comprehensive contracts irrespective of the underlying ownership structure, provided that the contracts are Pareto efficient. It might be because the issues of ownership and the survival of organizational forms have been primarily discussed in moral hazard situations where all the parties possess *symmetrical* information when contracts are signed (e.g., Hart and Holmström, 1987; Holmström and Tirole, 1987).³ If this is the case, the irrelevance hypothesis can be justified in a Coasian perspective by taking into account an *ex ante* market for contracts that are most efficient.

Indeed, if there exist precontractual informational asymmetries, this hypothesis no longer holds.⁴ For example, consider a principal-agent relationship with adverse selection. It is well known that the second-best incentive mechanisms designed by the principal, the owner, under adverse selection do not lead to efficient resource allocation except in trivial cases (e.g., Baron and Myerson, 1982; Guesnerie and Laffont, 1984). Here, should the agent be vested with ownership, i.e., the exclusive authority to decide the sharing rules subject to the principal breaking even, first-best resource allocation can in most cases be achieved. Of course, this would mean that it makes no sense

² Here we refer to contracts that are subject to some specific functional structures, such as constant wage contracts, sharecropping, equal profit sharing, etc. Alchian and Demsetz (1972) focus on the owner's monitoring role in a presumed context with fixed-form contracts.

³ That is, when the contracts are *ex ante* Pareto efficient, in the terminology of Holmström and Myerson (1983).

⁴ In this case, the contracts are *interim* Pareto efficient in the terminology of Holmström and Myerson (1983).

to have a principal. A fundamental reason for separation of ownership and management is perhaps precisely that agents are not wealthy enough to own all their activities.⁵ However, as the number of agents increases, it becomes more feasible that the agents can pool their financial resources and jointly own the firm.

In the light of the above discussion, we conclude that if ownership and efficiency were to be sensibly analyzed in a complete contracting framework, the models would have to take into account asymmetric information prior to the contracting date and include a group of agents who are able to own the firm. In fact, the existence of contracting parties possessing precontractual private information is not an unreasonable assumption. An individual certainly knows better than do others his own past history, his potential ability for the job, risk propensity, minimum reserve wage or utility, natural inclination for his profession, preference for hard work, etc., and all these factors can influence the other contracting individuals' utility or welfare.

This motivates us to formalize our firm in terms of a principal/multiple-agent relationship in the sense of Myerson (1982), where the agents who engage in team production, in the sense of Alchian and Demsetz (1972), possess private information concerning their own productivity and make private efforts that are not observable. Inevitably, this attempt leads us into some analytical intricacies, but recent developments in principal-agent theory offer ready tools for a tractable analysis.

In our context, ownership is understood as the right to set up rules concerning the distribution of earnings. Implicit in this view is the identification of the owner with the right to claim as much profit as possible, subject to legal restrictions, informational constraints, costs of decision making, and bargaining power of the contracting parties.⁶

⁵ Other reasons include vocational specialization for the agents and risk diversification for the investors.

⁶ Indeed, the concept of ownership or property rights is always in want of a good definition. Traditional legal definitions of ownership have been either too specific or too vague to be useful for developing penetrating insights into the survival of ownership structures. Recently, Grossman and Hart (1986) propose that ownership be defined as the purchase of the residual control rights over the physical assets that are left uncontracted for beforehand. Milgrom and Roberts (1989) point out that this definition would be problematic in its application, and suggest the alternative view that the owner is the one who collects residual returns rather than residual control. Traditional principal-agent models usually simply do not distinguish between the owner, the principal, the residual claimant, or the one who designs the profit-sharing rules. On the one hand, our conception of ownership recognizes the possible separation between ownership and the residual-profit claimancy. On the other hand, it extends the definition of Grossman and Hart in the following sense. At the start of a relationship, when no contracts have been signed beforehand, the residual control rights are nothing but the total control rights regarding the assets, including both tangible and intangible assets, to be used or disposed, which necessarily include the control right to design the incentive mechanisms concerning the sharing of future

Our major purpose in this paper is to compare the efficiency implications of two polar ownership structures, wherein the firm is viewed as a complete nexus of contracts. The first structure, called the absentee ownership, is formalized as a standard principal-agent model in which the residual claimant, the principal, is the absentee owner who designs the incentive mechanism to maximize his profit. The second structure, called the cooperative ownership, is formalized as a variation of the principal-agent models in which the agents are the collective owners of the firm who collectively design the incentive mechanism that maximizes the joint profits of the firm.⁷ In order to compare their efficiency implications, we construct the two models in such a way that they differ only in the underlying ownership structures. In particular, we assume the same rational beliefs and behavior of all the contracting parties irrespective of the underlying ownership structures.

An interesting observation is that under cooperative ownership, the optimal incentive mechanism can be first-best in that it eliminates all problems of adverse selection and moral hazard. This result may be perceived as an extension of the standard collective choice results (e.g., d'Aspremont and Gérard-Varet, 1979) to a situation in which the decision rules depend not only on each individual agent's hidden information, but also on his hidden action. In contrast, under absentee ownership, the optimal incentive mechanism is only second-best. This result suggests that potential advantages of cooperative ownership may not necessarily be limited to the philosophical, behavioral, or social aspects of life (see Bonin and Putterman, 1987) but may also be extended to the institutional aspect where potentially efficient incentive structures are feasible (see Estrin, 1991, for a similar, though unformalized, argument).

Important assumptions behind this rather strong result are (a) all the agents and investors are risk neutral, (b) there is a costless access to the external financial and insurance markets for both types of the firms, and (c) there are substantial profits to be shared. We discuss these assumptions when they are introduced.

The models are introduced in the next section, together with the definitions of incentive-compatible mechanisms and the concepts of equilibrium-solutions. In Section 3 we characterize the optimal incentive mechanisms under the two ownership structures. The proofs are relegated to the Appendix. In Section 4 we discuss the results and related issues. Section 5 concludes the paper.

cash flows that will be generated from the use of these assets. In Section 3 we show that, at least theoretically, the claimant of residual returns may not exhibit the proper incentive of an owner as we would expect.

⁷ In the present context, this objective is equivalent to maximizing an equally weighted sum of all the agents' utilities.

2. THE MODEL

2.1. The Setup

Suppose a firm is to be formed where n agents and a residual claimant are to undertake a profitable activity.⁸ Each agent, indexed $i \in N = \{1, \dots, n\}$, supplies unobservable effort $e^i \in A = [0, B]$ with a private nonmonetary cost or disutility $V^i: (e^i, \theta^i) \in A \times \Theta^i \rightarrow V^i(e^i, \theta^i) \in R$, where $\theta^i \in \Theta^i = [\underline{\theta}^i, \bar{\theta}^i]$ is a private efficiency parameter, known as the i th agent's type.

The agents are best thought of as specialized managers and workers, and we assume that none of them is dispensable.⁹ Note that the type variables θ^i are not really necessary if we only want to model heterogeneous utilities between the agents, since we already allow the disutility functions V^i to vary across the index i . The type variables serve to introduce the information asymmetries in the model. One way of introducing asymmetric information might be to simply assume that the functional form $V^i(\cdot)$ is only known by agent i himself, but this would render an unnecessary degree of complication to the problem. Instead, following the traditional adverse-selection literature, we assume that the form $V^i(\cdot)$ is public knowledge and we let the disutility of effort be parameterized by a private information parameter, notably θ^i for all $i \in N$. In this way the index i can be used to distinguish the observable differences among the agents, e.g., $i = 1$ represents a financial manager, $i = 2$ a marketing manager, $i = n$ a driver, etc. Further, each agent i can be viewed as chosen from a population of types θ^i . As such θ^i might be interpreted as either a measure of private cost efficiency for agent i or his private preference for effort.

Assume $V_e^i > 0$ (effort is costly), $V_{ee}^i > 0$ (effort also increases the marginal cost), $V_\theta^i < 0$ (higher type implies lower cost), and $V_{e\theta}^i < 0$ (higher type also implies lower marginal cost).¹⁰ Assume also that it is common belief that the agents' possible types are independently distributed and that their cumulative distribution and density functions are given by $F^i(\cdot)$ and $f^i(\cdot)$ on Θ^i [$f^i(\cdot) > 0$ on Θ^i]. Let $e = (e^1, \dots, e^n)$ and $\theta = (\theta^1, \dots, \theta^n)$. The agents' effort, together with some technology or assets, determine a monetary output. Let $x: e \in A^n \rightarrow x(e) \in R$ denote the output net of the costs of technology. We assume that $x(\cdot)$ is concave on A^n , strictly increasing in each argument, and twice continuously differentiable. In order to focus on effort allocations we assume that the technology requires a lump sum monetary investment and is normalized to zero. In the first model, the technology

⁸ The residual claimant can be a group of claimants who act as a single legal person.

⁹ It is plausible that standardized and/or dispensable jobs involve less problems of incentives, hence they are abstracted away.

¹⁰ When there is no ambiguity, we drop out the superscript of variables, e.g., the partial derivative of V^i w.r.t. θ^i is written V_θ^i instead of $V_{\theta^i}^i$, etc.

is exclusively owned by the residual claimant, called the principal; in the second model by the agents equally.¹¹

Let O_p denote the principal-owner's firm or absentee ownership. O_p can, in general, be interpreted as an organization that is characterized by the separation of ownership and management. Note that it may describe not only a classical capitalistic firm the owners of which are the shareholders, but also a state-owned enterprise so far as the objective of the firm is to maximize the expected profits net of wages.¹²

Let O_a denote the firm where the agents are the exclusive collective owners, thus cooperative ownership. Ownership forms nearest to O_a are partnerships, co-ops, labor-managed firms, etc. But it is worth noting that unlike most co-op models, in our cooperative the collective owners are allowed to interact with nonowner residual claimants.¹³

The essential problem is to see how the profits are to be shared by the agents and the residual claimant. We view this problem as the owner(s) designing the optimal incentive mechanisms or sharing rules under feasibility constraints. Let S^i denote the share of profits that goes to the i th agent, whose preference functions are assumed to be additively separable in money and effort and linear in money. The i th agent's utility thus is $\pi^i(S^i, e^i, \theta^i) = S^i - V^i(e^i, \theta^i)$. The profit net of payments to the agents, i.e., $W = x - \sum_i S^i$, goes to the residual claimant. All the agents and the residual claimant are assumed to be risk neutral and expected-utility maximizers.

2.2. Incentive-Compatible Mechanisms and Equilibrium Strategies

It bears repeating that the timing of contracts is important for our analysis. As mentioned in the Introduction, if contracting takes place before the agents' types are realized, ownership is an irrelevant issue. In the present context, we suppose that each agent has already been informed of his efficiency parameter prior to the contracting date. Thus the sharing rules have to be designed under incomplete information.

In general, the problem of incentive mechanism design is to characterize the interim Pareto-efficient decision rules (Holmström and Myerson,

¹¹ Equal sharing of ownership is a simplifying assumption. It avoids complicating the considerations in formalizing the cooperative's objective function. See Footnote 12.

¹² The case of mixed ownership with different parties such as absentee investors, managers, and workers holding different proportions of ownership shares is certainly an interesting subject that deserves being listed on the future research agenda.

¹³ In a pure team-moral-hazard context, the ability to interact with outside residual-profit claimants has been considered by Holmström (1982) as a distinguishing characteristic between the cooperative and the capitalist firms, with the former deprived of the access to the external financial and insurance markets. When we suppress this distinction, ownership becomes an irrelevant issue for efficiency in Holmström's context because of the absence of precontractual asymmetric information.

1983), that is, the rules that are incentive-feasible and incentive-compatible in the face of precontractual private information. Notably, interim Pareto efficiency is only a necessary condition for all the sensible sharing rules that could possibly be designed by the players via any sort of communication and bargaining. There is still a problem as to which particular rule should be selected on the Pareto frontier. In the case where a single individual, the principal, designs the contracts, this is hardly an issue, but in the cooperative case, where the agents are all entitled to participate in setting up the sharing rules, the matter becomes much complicated. Indeed, although we assume that the cooperative members act noncooperatively in revealing their private information and in choosing their effort levels, there is a cooperative game with incomplete information in the first place that they must play as to which particular incentive mechanism on the Pareto frontier they should collectively choose.¹⁴ In this paper, however, we are only interested in showing the existence of a particular set of Pareto-efficient rules that are consistent with the objective of utility as well as profit maximization, and that can achieve first-best production efficiency under the cooperative ownership structure. Thus the remaining problem boils down to a separate judgment of the cooperative's objectives (see the next subsection).

According to the revelation principle (Myerson, 1982; Forges, 1986), there is no loss of generality to consider mechanisms of the form $(S, e) = [(S^1, e^1), \dots, (S^n, e^n)]$, where $S^i: (x, \theta) \in R \times \Theta \rightarrow S^i(x, \theta) \in R$ is the share of profits to the i th agent, called the incentive contract, and $e^i: \theta \in \Theta \rightarrow e^i(\theta) \in R$ is the effort level recommended to the i th agent, called the effort recommendation.

An incentive mechanism determines an internal rule of the game. The game proceeds as follows. The owner(s) first commit(s) to a mechanism (S, e) . Then each agent announces a type $\hat{\theta}^i \in \Theta^i$ to the public.¹⁵ After the announcement, a specific incentive contract plus effort recommendation is determined, according to the mechanism, for each agent. Then, each agent makes some private effort and receives a share of profits according to the contract when the output x is realized.

In order to focus on the institutional effect of ownership structures, we use the same solution concept to characterize the agents' strategies. Irrespective of the ownership forms, we assume that the agents act noncooperatively in reporting private types and choosing their effort levels, and in forming their

¹⁴ See Myerson (1984) for the formalization of a general structure of cooperative games with incomplete information.

¹⁵ Strictly, the revelation principle applies only to the communication environment where the agents communicate separately and confidentially with the principal or via a mediator. But in the present context there is no loss of generality to limit our attention to the public communication environment, whereas doing so allows us to derive the optimal mechanisms more intuitively. For a more detailed discussion see Zou (1989).

beliefs about the other agents' strategies and beliefs. That is, each agent is concerned only about maximizing his own expected utility, even if it were to be achieved at the expense of the other agents' welfare or of the organization as a whole. Such an indiscriminating formalization of individual behavior under different ownership structures may have a tendency to overemphasize self-interested behavior for the cooperative, but we show that judiciously designed incentive mechanisms do exist that establish economic efficiency for such cooperatives.

Recently, MacLeod (1987) has proposed a behavioral distinction between cooperative and noncooperative organizations. He argues that "the Nash equilibrium concept is most appropriate when modeling a cooperative firm subject to incentive constraints, while the notion of dominant strategy implementation better models noncooperative organizations." Under this distinction, cooperative ownership is shown to achieve higher efficiency than noncooperative ownership. Since any dominant strategy equilibrium is a Nash equilibrium (e.g., Dasgupta et al., 1979), the above behavioral distinction implies weaker incentive constraints for the cooperatives, whence the dominance of cooperatives over noncooperative organizations. Intuitively, if we adopt MacLeod's view and extend this behavioral distinction to our context, the inefficiency of the absentee ownership would become, at least weakly, more severe.

Given an incentive mechanism (S, e) , each agent's strategy is a pair of functions $\hat{\theta}^i: \Theta^i \mapsto \Theta^i$ and $\hat{e}^i: \Theta \times \Theta^i \mapsto A$ such that the i th agent having type θ^i would choose to report $\hat{\theta}^i(\theta^i)$ and choose effort level $\hat{e}^i(\hat{\theta}, \theta^i)$ when $\hat{\theta}$ is the vector of reported types.

The solution concept that we use is an adaptation of the notion of *Bayesian Incentive Compatibility* proposed by d'Aspremont and Gérard-Varet (1979) to the present Bayesian game setting with both private types and effort. Let θ denote the vector of true types of the agents and let an incentive mechanism (S, e) be given. Write $e^{-i} = (e^1, \dots, e^{i-1}, e^{i+1}, \dots, e^n)$, $\theta^{-i} = (\theta^1, \dots, \theta^{i-1}, \theta^{i+1}, \dots, \theta^n)$. After the stage of communication, suppose that agent i has reported $\hat{\theta}^i$, and he expects that the other agents have reported their types truthfully and will follow the effort recommendation. his effort strategy should satisfy

$$\hat{e}^i(\hat{\theta}^i, \theta) \in \arg \max_{e^i} [S^i(x(e^i, e^{-i}(\hat{\theta}^i, \theta^{-i})), (\hat{\theta}^i, \theta^{-i})) - V^i(e^i, \theta^i)],$$

where we use $\hat{e}^i(\hat{\theta}^i, \theta)$ to denote $\hat{e}^i[(\hat{\theta}^i, \theta^{-i}), \theta^i]$.

DEFINITION. An incentive mechanism $[S(\cdot), e(\cdot)]$ is (*Bayesian*) *incentive compatible with public communication* (abbreviated to ICP) if and only if it satisfies the following conditions: for all $\theta^i \in \Theta^i$ and $i \in N$.

$$\theta^i \in \arg \max_{\hat{\theta}^i} E_{\theta^{-i}}$$

$$\times [S^i(x(\hat{e}^i(\hat{\theta}^i, \theta), e^{-i}(\hat{\theta}^i, \theta^{-i})), (\hat{\theta}^i, \theta^{-i})) - V^i(\hat{e}^i(\hat{\theta}^i, \theta), \theta^i)], \quad (1)$$

and for all $\theta \in \Theta$ and $i \in N$,

$$e^i(\theta) = \hat{e}^i(\theta^i, \theta) \in \arg \max_{e^i} [S^i(x(e^i, e^{-i}(\theta)), \theta) - V^i(e^i, \theta^i)], \quad (2)$$

where E_θ ($E_{\theta^{-i}}$) is the expectation operator over Θ ($\Theta \setminus \theta^i$).

By (1), given that all the other agents report their true types and follow the recommended effort levels, no agent wants to misreport his type in the communication stage. By (2), given that all the agents have reported their types honestly and all the other agents would choose the recommended effort levels, no agent can gain from not choosing his recommended effort level. Thus, the conditions (1) and (2) characterize a particular *communication equilibrium* (CE), (Forges, 1986; Myerson, 1986). We call such an equilibrium a *public communication equilibrium* (PCE). By the revelation principle there is no loss of generality to restrict attention to the set of CE (Forges, 1986) and in the present context, to that of PCE or ICP mechanisms (Zou, 1989).

A CE in the sense of Myerson and Forges relies on an uninformed mediator who communicates separately and confidentially with each agent. The revelation principle says that any arbitrary equilibrium strategies that are achievable via any sort of communication among the agents can also be implemented in an incentive-compatible mechanism in which all the agents report their private types honestly and follow the effort recommendation of the mediator. The difference between our PCE and the CE is that, after the phase of communication, in a CE an agent does not necessarily know the types that have been reported and the effort levels that will be chosen by the other agents, whereas, in a PCE he does know.

The reason for us to choose the PCE as a solution concept is twofold. First, as suggested in most cooperative or labor-management literature, decision making in a cooperative organization is a participatory and democratic process. Each member should be allowed to participate in setting up the profit-sharing rules, and it is most natural that discussions are made in public.¹⁶ Secondly, the PCE is a more restrictive concept than that of CE. That is, the set of the former equilibria is contained, often strictly, in that of the latter. Thus, the problem of multiple equilibria might tend to be less serious in adopting the PCE concept.¹⁷

Voluntary participation gives each agent the opportunity to require a minimal expected utility level, which we normalize to zero, at the start.¹⁸ Under

¹⁶ In fact this reasoning might also apply to most principal-owned firms since it is implausible that the principal, just by being the owner, is able to control all means of communication.

¹⁷ For more discussion on the problems of multiple equilibria, see Demski and Sappington (1984), Demski et al. (1988), Ma et al. (1988), Palfrey (1991), and Zou (1991).

¹⁸ If the initial investment has not been normalized to zero, we can allow each agent to require at least his share of the investment in the cooperative case.

the assumption that none of the agents is dispensable and assuming that the output is high enough to justify team production for all possible types, the following individual rationality constraints should be taken into account:

$$\pi^i(\theta^i) \stackrel{\text{def}}{=} E_{\theta-i}[S^i(x(e(\theta)), \theta) - V^i(e^i(\theta), \theta^i)] \geq 0, \quad \forall \theta^i \in \Theta^i, i \in N, (3)$$

where $\pi^i(\theta^i)$ is the i th agent's optimal expected utility given an ICP mechanism $(S(\theta), e(\theta))$.

2.3. Objective of the Firm

In O_p , the principal's objective is to maximize the expected profits net of the payments to the agents, subject to the incentive and the individual rationality constraints. That is,

P^p :

$$\max_{S, e} E_{\theta}[x(e(\theta)) - \sum_i S^i(x(e(\theta)), \theta)] \quad (4)$$

subject to (1), (2), and (3). This formulation captures the capitalistic nature of the absentee ownership; the owners do not make direct labor inputs and design the sharing rules that can best extract returns on their capital assets.

In O_a , there is no consensus on what should be the best specification of the objectives of a cooperative organization. Admittedly, the organizational goal of a cooperative may be influenced by its members' relative bargaining power, its internal organizational ideology, convention, consensus politics, and various other particulars. Given this variety, it is natural that there is no single and unanimously accepted formal definition of the cooperative's objectives. However, dividend maximization and utility maximization are the two most representative specifications of the cooperative's objectives in the labor-management literature. In the former definition, see, e.g., Bonin and Putterman (1987) and their references, cooperative members are assumed to maximize the firm's profits net of capital and labor costs, in the form of dividends that they share equally. In the latter definition the cooperative's goal is to maximize a typical member's utility (Miyazaki, 1984; and Tapiero, 1989). This definition is based on the assumption that all the cooperative members are identical.

In the present context, while suppressing the presumption that profits must be shared equally, we adapt the first definition, modified as profit maximization, as our cooperative's objective. Although income-equality has been traditionally considered as a distinct feature for labor-managed firms, it imposes an obvious constraint in designing the optimal institutional struc-

tures.¹⁹ The disincentive effect of equal profit-sharing becomes most acute when the organizational members possess private information and make private decisions, as in the present context. Since the costs of labor input, or the disutility of effort, are not publicly observable, the actually realized profit level, defined as the revenue net of capital and labor costs, necessarily depends on the agents honestly reporting their true costs. But if profits were to be shared equally, every agent would have an incentive to exaggerate his true cost and to make as little effort as possible. Above all, as mentioned in the Introduction, our ultimate goal here is not a positive description of bona fide cooperative firms, but to show, at least in theory, that the cooperative ownership structure implies feasible institutional arrangement that achieves production and allocational efficiency.

There are three major reasons for us to choose the profit-maximization definition. First, assuming profit maximization brings the cooperative's objective closely in line with that of the absentee-owner's firm. This allows us to highlight the essential cause for different efficiency results under different ownership structures. Second, since our agents are different in quality and in preference for effort, there is a problem of choosing the right utility function in the utility-maximization approach. A plausible choice is to give every agent an equal weight and assume that a typical agent's utility, or an average utility, is the sum of all the agents' utilities divided by the number of the agents. If this average utility is to be maximized, it is equivalent to maximizing simply the sum of all the agents' utilities. Nevertheless, the question would still be left unanswered why different agents should be given the same weight. The third reason is more of an observation. While profit maximization and utility maximization are distinct in interpretations, they may lead to the same problem formulation and hence the same analytical results, specially when the agents are assumed income risk neutral. As shown below, this happens to be true in our model, in which the expected budget-balancing condition establishes an equivalence relationship between profit maximization and maximization of the sum of the agents' utilities.

The expected budget-balancing condition is formally defined as

$$E_{\theta}[x(e(\theta)) - \sum_i S^i(x(e(\theta)), \theta)] = 0. \quad (5)$$

Note that here we use a less restrictive condition, i.e., we require that the cooperative's budget only to be balanced *ex ante*. This relaxation is crucial for deriving an efficiency result for the cooperatives. To understand this condition, it might be helpful to think alternatively of a closed cooperative

¹⁹ In a moral hazard context where weaker conditions such as "envy-free" and "fairness" are used to define equity, Macleod (1988) shows that efficient allocations can be achieved in the cooperatives.

firm that has no interactions with the outside financial world. Then, the jointly realized output must always be shared among the agents or else it would be impossible to account for a shortage or excess of the payments. This implies a more conventional *ex post* budget-balancing constraint:

$$x(e) - \sum_i S^i(x(e), \theta) = 0, \quad \forall e \in A^n, \forall \theta \in \Theta. \quad (6)$$

As is shown by Holmström (1982), under the *ex post* budget-balancing condition a first-best solution will not be attained even if there are no informational asymmetries among the agents.²⁰ This suggests that the cooperative members can be better off if, as we assume here, they can find a residual claimant to help them break the *ex post* budget constraint. On the other hand, in order to avoid expected shortage or excess of payments, it is still necessary to consider an expected or *ex ante* budget-balancing condition, which is given by (5). Thus, perhaps more to the point, condition (5) could also be called a budget-breaking condition. We would argue in the present context that it is not unreasonable to allow the cooperatives to have resort to outside risk-neutral investors in resolving their budget balancing problems. We show later that typical moral hazard problems associated with outside financing, e.g., Jensen and Meckling (1976, 1979), do not occur in our model.

The cooperative's problem can now be stated as

P^a

$$\max_{S, e} E_\theta[x(e(\theta)) - \sum_i V^i(e^i(\theta), \theta^i)] \quad (7)$$

subject to (1), (2), (3), and (5). Note that substituting the budget balancing condition (5) into the objective function (7) yields an equivalent utility-maximizing objective

$$\max_{S, e} E_\theta \sum_i [S^i(x(e(\theta)), \theta) - V^i(e^i(\theta), \theta^i)]. \quad (8)$$

This shows that profit maximization is equivalent to maximizing the sum of all the agents' utilities, giving each agent the same weight. Deviding this sum by N would give us another equivalent expression that can be interpreted as

²⁰ To be more precise, Holmström shows that the *ex post* budget-balancing constraint precludes cooperatives from achieving efficiency when all the agents are risk neutral. If agents are risk averse, Rasmusen (1987) shows that efficient budget-balancing contracts may exist. These contracts can take the form of a random scapegoat contract, in which one agent is chosen to be penalized when output is low, or of a random massacre contract, in which one agent receives the entire output and the rest are penalized. The budget-balancing conditions have been extensively discussed in the collective choice literature. For example, see Groves and Ledyard (1977), and d'Aspremont and Gérard-Varet (1979).

the maximization of a typical agent's utility. Obviously, if all the agents were identical, we would go back to the traditional utility-maximization definition of the cooperatives' objectives.

It is clear that both models involve problems of team moral hazard (see Holmström, 1982) and adverse selection. Moral hazard stems from the unobservability of effort, which gives each agent the opportunity to reduce effort while not bearing the full consequence of the reduced output. Adverse selection stems from the uncertainty of each agent's type, which enables the agents to enjoy some information rents, as will be clear later. The next section is devoted to solving problems P^p and P^a .

3. OPTIMAL INCENTIVE MECHANISMS

3.1. First-Best Solution

Before we proceed, it is useful to see what solution one could obtain under complete and perfect information, i.e., when the realization of θ is common knowledge and when all the agents' effort levels are publicly observable. This will serve as a benchmark for our subsequent comparative analysis.

DEFINITION. A mechanism $(S, e): \Theta \rightarrow R^n \times A^n$ is first-best if it solves the following problem for all $\theta \in \Theta$:

P^f :

$$\max_{S, e} [x(e(\theta)) - \sum_i V^i(e^i(\theta), \theta^i)], \quad (9)$$

subject to

$$[S^i(x(e(\theta)), \theta) - V^i(e^i(\theta), \theta^i)] \geq 0, \quad \forall i \in N. \quad (10)$$

If an interior solution to P^f exists for all $\theta \in \Theta$, the optimal solution, denoted $(S^f(\theta), e^f(\theta))$, should satisfy the first-order condition when each agent chooses the effort level that equates his marginal cost of effort with the marginal expected output, i.e.,

$$x_{e^i}(e^f(\theta)) - V_{e^i}^i(e^f(\theta), \theta^i) = 0, \quad \forall \theta \in \Theta, i \in N, \quad (11)$$

and the individual rationality condition when the expected profit share to each agent is higher than his cost:

$$S^f(x(e^f(\theta)), \theta) \geq V^i(e^f(\theta), \theta^i), \quad \forall \theta \in \Theta, i \in N. \quad (12)$$

In order for our analysis to make sense, and for ease of derivations of the optimal solutions, we make some assumptions on the preference and distribution functions.

A1. For all $\theta \in \Theta$ and $i \in N$,

(i) $V_{e^i}^i(0^+, \theta^i) = 0$ and $V_{e^i}^i(B^-, \theta^i) = \infty$;

(ii) For $e^f(\theta)$ satisfying (11), $x(e^f(\theta)) \gg \sum_{i=1}^n V^i(e^f(\theta), \theta^i)$.

A2. For all $\theta^i \in \Theta^i$ and $i \in N$, $k^i(\theta^i) \leq 1$, where $k^i(\theta^i) = (1 - F^i(\theta^i))/f^i(\theta^i)$.

A3. For all $\theta^i \in \Theta^i$, $e \in [0, B]$, and $i \in N$, $V_{ee}^i \leq 0$ and $V_{e\theta}^i \geq 0$.

In assumption A1 the symbols 0^+ and B^- denote the limits as effort e^i approaches 0 from the right and B from the left, respectively; the symbol " \gg " means "be sufficiently larger." Intuitively, A1 (i) says that the agents' marginal cost of effort is negligible when the effort level is sufficiently low, and is prohibitively high when the effort level is close to their upper limit of capacity. Think, e.g., of effort as a measure of intensity or hours per day of work. A1 (ii) is a simplifying assumption, which says that, for all types of agents, team production is justified in that, under the optimal effort allocation, there is substantial amount of profits to be created.²¹ This assumption is actually not necessary for our comparative results, though it helps ensure a first-best solution for the cooperatives.

A2 is a technical assumption, commonly called the hazard rate condition. It is widely used in solving adverse selection problems and the design of auctions. Although it is difficult to find straightforward interpretations for this assumption, a class of interesting distributions do meet this requirement, including the uniform distribution.²² Again, this assumption is not necessary for deriving optimal solutions, although a more fastidious analysis would be inevitable without it.²³

We have assumed earlier that $V_{ee}^i < 0$, which means that for one unit increase in the level of effort the more efficient agent requires a smaller increase in compensation to maintain the same utility level than the less efficient agent. The first part of assumption A3 says that such differences between more and less efficient agents tend to be more significant as the level of effort grows larger. This seems to be plausible because, intuitively, it should be in fulfilling the more challenging tasks that the differences in ability are more easily revealed. The second part of A3 means that the above difference between more and less efficient agents tends to be less significant

²¹ According to Alchian and Demsetz (1972), team production is justified when several types of private resources, such as effort, are used, each provided by a different agent, and the joint output is greater than the sum of separable outputs of each cooperating agent's resource input.

²² See McAfee and McMillan (1987) for a statistic interpretation of $k^i(\theta^i)$. Sometimes a stronger monotone hazard rate condition is adopted, written as $d[f^i(\theta^i)/(1 - F^i(\theta^i))]/d\theta^i \geq 0$ (e.g., Wilson, 1983). Using a linear transformation of types: $t^i = \bar{\theta}^i + \underline{\theta}^i - \theta^i$, the monotone hazard rate condition can also be written as $d[G^i(t^i)/g^i(t^i)]/dt^i \geq 0$, where $G(t^i) = 1 - F^i(\bar{\theta}^i + \underline{\theta}^i - t^i)$ and $g^i(t^i) = G''(t^i)$. See Baron and Besanko (1984) for more examples of the distributions meeting this condition.

²³ For an impression, see Baron and Myerson (1982) and Maskin and Riley (1984). They derive optimal solutions under pure adverse selection in a single-agent context without this hazard rate condition.

as the efficiency parameter grows large. Perhaps it is easiest to think of θ^i as the amount of past personal investment in ability, through education, for example, and then $V_{e\theta}^i \geq 0$ could be interpreted as some sort of diminishing rate of return in this investment. Thus this assumption seems also reasonable.

3.2. Optimal Incentive Mechanism under Absentee-Ownership

We first present the proposition, then discuss the result.

PROPOSITION 1. *Under A1–A3, there exists an optimal solution to \mathbf{P}^p : $(S^p(x, \theta), e^p(\theta)) = [(S^{p1}(x, \theta), e^{p1}(\theta)), \dots, (S^{pn}(x, \theta), e^{pn}(\theta))]$. It satisfies $e^p(\theta) = \tilde{e}(\theta)$ and*

$$S^{pi}(x, \theta) = \tilde{S}^i(\theta) + D^i(\theta)[x - x(\tilde{e}(\theta))], \quad (13)$$

where $D^i(\theta) = V_e^i(\tilde{e}^i(\theta), \theta^i)/x_{e^i}(\tilde{e}(\theta))$ and $(\tilde{S}(\theta), \tilde{e}(\theta))$ satisfies that for all $\theta \in \Theta$ and $i \in N$,

$$x_{e^i}(\tilde{e}(\theta)) - V_e^i(\tilde{e}^i(\theta), \theta^i) + k^i(\theta^i)V_{e\theta}^i(\tilde{e}^i(\theta), \theta^i) = 0, \quad (14)$$

$$\tilde{S}^i(\theta) = \tilde{\pi}^i(\theta^i) + V^i(\tilde{e}^i(\theta), \theta^i) \quad (15)$$

$$\tilde{\pi}^i(\theta^i) = - \int_{\theta^i}^{\theta^i} \int_{\Theta^{-i}} V_{\theta}^i(\tilde{e}^i(\tilde{\theta}), \tilde{\theta}^i) dF^{-i}(\tilde{\theta}^{-i}) d\tilde{\theta}, \quad (16)$$

where $\Theta^{-i} = \Theta \setminus \Theta^i$ and $dF^{-i}(\theta^{-i}) = \prod_{j \neq i} dF^j(\theta^j)$.

Proof. See the Appendix.²⁴

From (13) we can see that the incentive contract for each agent is a linear function of x , the slope of which is given by $D^i(\theta)$. In the equilibrium where all the agents report honestly their private information θ and choose the recommended effort levels \tilde{e} , the payment to agent i is $\tilde{S}^i(\theta)$, and the utility of agent i is $\tilde{\pi}^i(\theta^i)$. If effort were contractable, the payment–effort vector pair $(\tilde{S}(\theta), \tilde{e}(\theta))$ would represent an incentive-compatible mechanism with pure adverse selection. The proposition is thus an extension of the observation in single-agent settings that with risk-neutral agents, the principal can costlessly implement a pure adverse selection solution, i.e., eliminate completely the

²⁴ This proposition is based on a more general result in Zou (1989). In preparing the last revision of this paper, I came across two other independent articles that present similar results to this proposition, namely Picard and Rey (1990) and McAfee and McMillan (1991). We will not discuss in detail the similarities and differences of our result as compared to these authors', except for two brief remarks. Whereas their models are formalized in an implementation framework, we formulate the problems in terms of the notion of PCE. Also, while these authors focus more on the analytical aspects of the problems, our central theme here is to compare efficiency implications of the optimal institutions under different ownership structures.

problem of moral hazard, even when effort is not observable (e.g., Laffont and Tirole, 1986; Picard, 1987; Guesnerie et al., 1989; and Zou, 1992).

We also see from (16) that the agents, except for those whose types are the lowest, enjoy a strictly positive utility level. This amount is commonly perceived as the agent's information rents. Following the convention, we call (S^p, e^p) the second-best incentive mechanism. It is second best because the principal cannot extract all the agents' information rents as he can under complete information, and because the agents do not provide the socially most efficient effort levels in this incentive mechanism.

That separation of ownership and management would result in inefficiency is not at all a new observation (e.g., see the celebrated book of Berle and Means, 1932). Explicit recognition of conflicting interests and informational asymmetries between the principal and the agents allows one to assert that inefficiency is almost a rule rather than exception in modern corporations. The source of inefficiency is best seen from equation (14), which is a familiar characterization of solutions dealing with pure adverse selection problems (e.g., Baron and Myerson, 1982; Guesnerie and Laffont, 1984). Comparing it with the characterization of the first-best solution (11), we find an extra term $k^i V_{e^i}^i$ in (14). This term might be loosely interpreted as some sort of extra marginal cost for the principal to induce agent i , who has θ^i , to increase effort, owing to the incentive compatibility constraint (1).²⁵ The conflict of interests between the principal and the agents probably is the most serious barrier that prevents a firm under absentee ownership from achieving economic efficiency. With the principal trying to maximize the residual profit on the one side and the agents trying to secure their information rents on the other, the best solution the contracting parties can achieve is shown to be an expensive compromise. We will have more insight into the source of inefficiency after deriving the solution to the cooperative's problem.

Before we proceed, it is interesting to have a look at a special case where all the agents' types are public knowledge. The optimal solution can be derived by simply taking the limit as $\underline{\theta}^i \rightarrow \bar{\theta}^i$ for all $i \in N$ in (14) and (16). This would yield a first-best solution since $k^i(\theta^i)$ in (14) would degenerate to zero. Moreover, each agent's profit would also shrink to zero according to (16). Eliminating the adverse selection problem this way, our model boils down to the pure team-moral-hazard model of Holmström (1982). The difference is that we derive an efficient effort allocation using linear incentive contracts, whereas Holmström chooses step functions. The existence of such variety of ways to restore efficiency with a principal breaking the budget constraint for the team has already been noted by Holmström (1982).

²⁵ See Zou (1992) for a more detailed analysis of a similar condition in a single-agent context.

3.3. Optimal Incentive Mechanism under Cooperative Ownership

Now we turn to solving the problem of the cooperative. The derivation is quite similar to that under the absentee ownership except for a different objective function and an extra budget-balancing constraint.

PROPOSITION 2. *Under A1, there exists an optimal solution to \mathbf{P}^a . Denote this solution by $(S^a(x, \theta), e^a(\theta))$. It satisfies $e^a(\theta) = e^*(\theta)$ and*

$$S^{ai}(x, \theta) = S^{*i}(\theta) + [x - x(e^*(\theta))], \quad (17)$$

where $(S^*(\theta), e^*(\theta))$ satisfies that for all $\theta \in \Theta$ and $i \in N$,

$$x_{e^i}(e^*(\theta)) - V_{e^i}(e^*(\theta), \theta^i) = 0, \quad \forall i \in N, \theta \in \Theta, \quad (18)$$

$$S^{*i}(\theta) = \pi^{*i}(\theta^i) + V^i(e^{*i}(\theta), \theta^i) \quad (19)$$

$$\pi^{*i}(\theta^i) = - \int_{\theta^i}^{\theta^i} \int_{\Theta^{-i}} V_{\theta^i}^i(e^{*i}(\tilde{\theta}), \tilde{\theta}^i) dF^{-i}(\tilde{\theta}^{-i}) d\tilde{\theta}^i + \alpha^i, \quad \forall i \in N, \quad (20)$$

$$\alpha^i \geq 0, i \in N, \quad (21)$$

and

$$\int_{\Theta} [x(e^*(\theta)) - \sum_i S^{*i}(\theta)] dF(\theta) = 0 \quad (22)$$

Proof. See the Appendix.

Equations (18), (19), and (20) are the conditions parallel to the characterizations (14), (15), and (16), respectively. It is clear by comparing (18) with (11) that the solution to \mathbf{P}^a attains a first-best effort allocation. In some sense this result is an extension of d'Aspremont and Gérard-Varet (1979) who analyze extensively the same problem with multiple agents in a public good context. Under proper conditions, d'Aspremont and Gérard-Varet show that efficient allocation can be achieved despite the presence of hidden information the agents possess. Our model is more general in that the agents now not only possess private information, but also make private effort. As mentioned earlier, a residual nonowner's role to help relax the budget-balancing condition into an expected one is indispensable for our solution in the present context.

In this solution we note that each agent's expected utility now consists of two parts [see (20)]. The first part, $-\int_{\theta^i}^{\theta^i} \int_{\Theta^{-i}} V_{\theta^i}^i(e^{*i}(\tilde{\theta}), \tilde{\theta}^i) dF^{-i}(\tilde{\theta}^{-i}) d\tilde{\theta}^i$, is similar in form to that in the solution to \mathbf{P}^p [see (16)]. We keep calling this amount the agent's private information rents. This amount is the minimum that is required to guarantee that agent i will report truthfully his type and choose the first-best effort. Apart from that, α^i is the share of the extra profits left unused for the incentive purposes. We have assumed (see A1) that the

first-best expected output is sufficiently higher than the joint costs of all the agents. This assumption can now be made more specific as to require that the extra earnings are higher than the sum of the expected information rents to all the agents. This allows α^i to be positive for all $i \in N$ (see the proof in the Appendix).

The difference in the power of incentives in the optimal sharing rules under the two ownership structures can be seen by comparing (13) with (17). Using (14), the slope D^i of the incentive contract in (13) lies between 0 and 1. The higher D^i is, the higher is the incentive power of the contract. The first-best allocation can only be established when $D^i = 1$ for all $\theta^i \in \Theta^i$ and $i \in N$, which is achieved in the cooperative's solution.

But what is the intuition behind this first-best solution? Perhaps the easiest way is to look at the derived cooperative's objective function (8). The objective of maximizing the equality weighted sum of all the members' utilities aligns the individuals' interests with that of the firm as a whole. Since the agents' utilities take the form of information rents, in our cooperative what is supposed to be maximized is exactly the sum of all the agents' information rents, possibly plus a share of the residuals, i.e., α^i . Further, from (16) and (20) each agent i 's utility π^i can be seen as a functional of the effort recommendation function $e^i(\cdot)$. Since $V_{e\theta}^i < 0$, π^i increases in e^i , this implies that if higher effort were to be recommended for a given report θ , the agents' utilities or information rents must also increase correspondingly in order to induce truthful report of information. The optimal upper bound for $e^i(\cdot)$ is the first-best effort function $e^{fi}(\cdot)$. In the absentee's case, when e^i exceeds \tilde{e}^i , the principal's expected utility diminishes because the total marginal information rents start to outweigh the marginal output, whence the second-best effort levels \tilde{e}^i . Whereas, in the cooperative's case, provided that the potential profits are high enough, information rents can be optimized by setting $e^* = e^f$.

It is worth remarking that none of the agents or no subgroup of the agents should be able to claim an amount more than $\sum \alpha^i$ on top of their maximum information rents. Otherwise some other agents necessarily receive lower information rents and the first-best solution would not be feasible any more. This is why in characterizing the optimal solutions to the cooperative's problem we have specified as a necessary condition that all the constant amount α^i are nonnegative. Note, however, that we have assumed that none of the agents is dispensable for the cooperative's production. Since in our solution all the members of the cooperative receives a higher expected utility level than their reserved utility, no member can credibly threaten to break away in order to claim a higher share of profits. Therefore what we have identified is a reasonable class of feasible optimal mechanisms that achieve first-best efficiency, although other less efficient, and probably less reasonable, mechanisms may also exist. In those organizations where the members uphold

certain distributional rules as an utmost criterion, e.g., egalitarianism, and efficiency is only of secondary concern, the optimal incentive mechanism prescribed in (18)–(22) would no longer be suitable.

Admittedly, this first-best allocation in the cooperative is derived under a rather particular assumption that optimal joint output substantially exceeds joint costs. If this were not the case, a second-best solution would also result for the cooperative. Nevertheless, from the above analysis, it is intuitive that even if the cooperative cannot achieve a first-best contracting solution in cases where assumption A1 does not hold, the optimal arrangement under the cooperative ownership would still be superior to that under absentee ownership. This is because the agents in the cooperative, by definition having all the claims on the expected profits, have always more profits to share than in the absentee owner's organization, provided that the potential profits for the firm are positive. These extra claims could be used to increase the incentives for the agents.²⁶

The constant terms α^i in the cooperative's optimal solution can be settled quite arbitrarily, provided that they are positive and their sum satisfies the expected budget-balancing condition (22). For instance, recollect that we have let the output x denote the revenue net of the costs of capital. If, say, each cooperative member must contribute a share of the capital for the purchase of technology or assets, and this constitutes part of the sharing rules, then α^i may be determined pro rata, according to the shares of the capital contributions among the agents as an extra return on equity. But if equality of income is given more preference, it is also feasible to set $\alpha^i = \alpha$ for all i irrespective of the agents' share of capital contributions. Note again that the amount $\sum \alpha^i$ is the extra profits after capital costs and the total information rents. This arrangement could be viewed as giving efficiency the first priority and equality in income the second. In our case, since all the agents share the capital investment equally, equal sharing of extra profits seems to be the most plausible solution. In sum, when there is a surplus of expected profits net of capital and information rents, there are infinitely many ways to share it.

4. FURTHER DISCUSSION

4.1. *The Monitoring Issue*

In rationalizing the existence of the capitalist firms Alchian and Demsetz (1972) have proposed a hypothesis concerning the principal's role as a monitor. They argue that moral hazard on the part of agents engenders inefficiency, and thus necessitates supervision. In order to avoid moral hazard on

²⁶ A more rigorous analysis for this case is being attempted in a subsequent paper.

the part of the monitor, according to Alchian and Demsetz, it is best to let the residual claimant, who is identified with the owner, perform the monitoring role. This hypothesis has received some scepticism recently. Holmström (1982) contends that the principal's role is not essentially one of monitoring. He shows that with a principal enforcing penalties for underproduction of joint output, judiciously designed contracts alone can completely eliminate inefficiency caused by team moral hazard. In a fixed-form contracting framework, i.e., where the forms of contracts are not freely chosen but subject to exogenous constraints, Putterman and Skillman (1988) further show that monitoring does not necessarily improve efficiency. The incentive effect of supervision is shown to be critically dependent on the incentive schemes employed, the risk preferences of the agents, and the degree of informativeness of monitoring.

An immediate corollary of our cooperative's efficiency solution is that under the cooperative ownership structure monitoring is not necessarily valuable even with precontractual asymmetric information. This result extends Holmström's (1982) observation to the present context involving both moral hazard and adverse selection. What is more interesting here is that Alchian and Demsetz's argument appears to become self-fulfilling in our principal-owner's firm: the separation of ownership and management engenders inefficiency, as we have shown, and this inefficiency may be mitigated if the principal is able to monitor the agents' individual performances. In other words, in situations where there is room for monitoring to improve efficiency, the principal's role may be justified; but the existence of the principal as an exclusive owner may be the very cause that leads to such a situation. Since monitoring is usually imperfect and costly, our qualitative comparative result would not alter even if the absentee owner engages himself in active supervision of the agents' effort. Our observation might thus also be seen as a substantiation of Putterman and Skillman's (1988) argument that in comparing the efficiency implications of different ownership structures, the effect of monitoring should succumb to the firm's incentive structures on which ownership has a most direct impact.²⁷

4.2. Moral Hazard on the Residual Claimant

We have argued that the residual revenue claimant does not have to be a residual control claimant, therefore does not have to be an owner. His function is more of that of an insurer who helps the cooperative to implement an optimal incentive mechanism. The agents and the residual claimant only need to sign a contract that legalizes the residual claimant's right to receive Δ

²⁷ Putterman and Skillman (1988) refer to the profit-sharing arrangement. See their references for empirical evidences that profit-sharing enhances efficiency.

$= x - \sum_i S^a_i$ when $\Delta \geq 0$ and the obligation to pay the amount $-\Delta$ when $\Delta < 0$. This residual claimant will not face moral hazard problems. A second look at the sharing rule (S^a, e^a) as defined in (17) reveals that the problem the residual claimant faces is quite benign from his point of view. Under the sharing rules (S^a, e^a) , the agents can shift the outcome distribution to the detriment of the residual claimant only by providing more effort than required, for the expected residual equals $(n-1)[x(e^*) - x(e)]$. But the marginal benefit from providing extra effort is a public good since it is shared by all the agents, while the marginal cost is borne individually. Thus no agent would like to increase the effort above the first-best level. It is also clear the agents do not have any incentive to make less than the first-best effort levels as well.

Here we find a very special type of residual claimants. Though their income takes the form of a residual return, it is actually negatively correlated to the net profits of the firm.²⁸ The theoretical possibility of such type of residual claimant points to the difficulty of generalizing the residual claimant as the owner of the firm, since the former does not necessarily have the proper objective of the owner, i.e., maximizing the firm's expected profits, as we would expect.

A similar observation can be found in Eswaran and Kotwal (1984). They show that the group-penalty scheme proposed by Holmström (1982) is subject to a serious potential moral hazard problem on the part of the principal. Implicit in our modeling, as well as that of Holmström, is that the residual claimant cannot make any covert side contracts with one of the agents. If he could, a side clandestine contract that gives any chosen agent a higher payment for under production would effectively induce this agent to shirk. This effect is most serious in Holmström's group-penalty scheme because the residual claimant receives all the jointly realized output whenever the output falls short of the optimal one. In our optimal solution, the temptation for the residual claimant to collude with an agent is less devastating because our contracts take a linear form rather than a step-function form, but it is still present. This point is best seen by a comparison between the marginal utility of the residual claimant and that of any single agent, say agent 1, if agent 1 reduces his effort by Δe^1 . In the equilibrium where all the other agents are expected to choose their optimal effort levels, agent 1's marginal utility is approximately zero since he maximizes utility in choosing effort in the equilibrium. The residual claimant's marginal utility would increase by $(n-1)x_{e^1}(e^*)\Delta e^1$. This clearly gives room for a collusion between the residual claimant and the agent.

However, this potential moral hazard problem on the part of the residual

²⁸ Whether such residual claimants exist in the real world is, of course, an empirical issue.

claimant is not just for the cooperative but may also exist for the absentee owner's firm, although probably to a lesser degree.²⁹ In the absentee's solution any single agent's marginal utility in effort remains at zero but the principal's marginal utility in any agent i 's effort reduction of Δe^i is $(\sum D^i(\theta) - 1)x_{e^i}(\tilde{e})\Delta e^i$. As long as $\sum D^i(\theta) - 1 > 0$, the principal has an incentive to collude with one of the agents. This hazardous temptation vanishes only if $\sum D^i \leq 1$.

These observations indicate that theoretical contractual arrangements can be subject to practical limitations, and that much effort is yet to be made in understanding the firm as a nexus of contracts. At this stage, we could possibly justify our analysis by pointing out that secret side contracts of the sort as discussed above can be easily made illegal by the contracting parties and that illegal contracts are hard to enforce. Even if a clandestine agreement is implemented there might be a chance for other parties to discover it *ex post*. The severer penalty *ex post*, enforced by law, may deter the residual claimant from conducting this illegal activity.

4.3. Collusion Among the Agents

Another interesting problem concerns the possible coordination of strategies among the agents against the residual claimant. Although we have assumed away this type of problem by adopting the noncooperative solution concepts to characterize the games, the problem is unlikely to be unreal in practice. Moreover, even if we stick to the present noncooperative framework, there still can be tacit collusion among the agents. This latter type of the problem is known as the multiple-equilibrium problem and is being dealt with in a growing literature (e.g., Demski and Sappington, 1984; Demski et al., 1988; Ma et al., 1988; Palfrey, 1991; Zou, 1991, etc.). It has been recognized that an incentive-compatible mechanism may induce other equilibria than the one desired by the principal. That is, given an incentive-compatible mechanism, collective cheating, or deviating from the recommended effort levels may constitute other equilibria in which all the agents expect higher utility to the detriment of the principal, or, more generally, to the residual claimant. Should this type of collusion be latent, the residual claimant contracting with a more cooperative team would expect a higher chance to be deceived and therefore would very likely to demand a higher risk premium or simply shun financing or insuring a cooperative. This probably is one of the reasons why cooperatives tend to have more difficulties in competing

²⁹ This observation is due to a referee.

with capitalist firms for external financing or insurance.³⁰ However, it is worth noting that agents in an absentee-owner's firm have the same incentive to collude, except probably to a lesser degree. In order to understand the precise impact of possible collusion we must thus have a consistent model for both types of the firms.

4.4. *Risk Preferences*

Some commentators on the success and demise of labor-managed firms (LMFs) maintain that the member-workers' incentive to share income and employment risk provides a rationale for the formation of the LMFs, whereas profit sharing among members provides a rationale for the dissolution of the LMFs (see, e.g., Miyazaki, 1984; and Martin, 1991). These hypotheses rely on the assumptions that the workers are risk averse and that the firm can freely adjust its size of membership over time. None of these assumptions are present in our model. Instead, the risk-neutral assumption plays a quite important role in our efficiency solution to the incentive problem of the cooperative firm.³¹ Our result may thus be seen as providing another rationale for the existence of the LMFs which is more closely dependent on the firm's underlying ownership structure, and which does not depend on risk sharing.

However, since the efficiency superiority of the cooperative in our context is derived from the firm's ability to design efficient profit-sharing rules, our finding is somehow at variance with the second hypothesis that profit sharing is detrimental to the survival of the LMFs. Intuitively, this hypothesis applies to a fixed-form contracting framework where only equal profit-sharing rules are considered and applied to all the members, including the old ones and the new ones, which provide disincentive for the incumbent members to absorb new members and dilute their ownership. An unverified conjecture is that if periodical contracts are allowed to maximize the existing members'

³⁰ See, e.g., Jones and Svejnar (1982), Stephen (1982), Miyazaki (1984), and Gintis (1989). Other proposed reasons include the traditional xenophobia of the capitalist economy towards the workers' cooperatives (Horvat, 1982), the impossibility of renting intangible assets when the cooperative is viewed as a pure rental firm (Jensen and Meckling, 1979), and the incompatibility between residual claimancy and the right of control (Putterman, 1982; Williamson, 1984). The possible hazard of collusion among cooperative members that faces the firm's residual claimant is more in line with that considered by Putterman (1982) and Williamson (1984).

³¹ If the agents are risk averse, a first-best solution to the cooperative's problem might still be derived using other contractual forms in this context, where the production uncertainty centers only on the endogenous variables, i.e., the agents' types and effort. But when there is also exogenous random variables that influence the final output, the risk-neutral assumption is more likely to be necessary for a first-best solution (see Zou, 1989; Picard and Rey, 1990; and McAfee and McMillan, 1991).

utility subject to that the new members break even, they might give the existing members more opportunities to expand their membership.

5. CONCLUSION

In this paper we have considered two extreme cases of a firm's ownership structure: one with complete separation of ownership and management, the other with complete overlap of ownership and management. We have derived explicitly the optimal ICP mechanisms under the two ownership structures and shown that the public communication equilibrium derived under the former structure does not attain the socially most efficient output while it does under the latter structure. This suggests that the ownership structure of an organization, even viewed as a comprehensive contract, matters for its economic efficiency, and that the collective ownership structure with the operating agents, managers, workers, etc., being the owners of the firm can be an efficient form of organization.³²

This theoretical observation is probably most suitable to explain the widespread practice of partnerships among physicians, accountants, consultants, etc., where the members' financial capacities are more likely to meet the relatively modest capital requirement. In reality, even a medium-sized firm can involve huge amounts of capital investment, far exceeding the wealth capacity of the employees as a whole. Limited liability law will prevent the agents from issuing riskless debts to finance projects. Moreover, specialized managers or workers already have a stake of their human resources in their company. If they are risk averse, it can be prohibitively costly, in terms of the risk premiums, to let them bear all the firm-specific financial risks.

Therefore, our comparative result remains purely a normative hypothesis, whose relevance or applicability are subject to critical verifications of the assumptions employed. In a separate article we continue this line of research to investigate the joint-ownership structure, wherein the firm is jointly owned by outside investors and the employees, the case of Employee Stock Ownership Plans (ESOPs), for instance. The welfare implications of different ownership distributions for each group will be examined in a more general model involving risk aversion and limited liability. It is also tempting to investigate the efficiency implications of the optimal incentive structure under collective ownership without external residual claimants. In this case team moral hazard would cause efficiency losses under cooperative ownership (Holmström, 1982), and we might find interesting trade-offs between

³² The dependence of a firm's efficiency on its organizational structures have also been noticed in different adverse selection contexts, e.g., Miyazaki (1977) and Boyd, Prescott, and Smith (1988), though the issue of ownership has not been addressed explicitly. See also Pint (1991) and Roemer and Silvestre (1989).

internalizing ownership and separating ownership from management. The analysis in this paper has shown promising signs of a fruitful discussion about ownership and efficiency using the incentive mechanism approach.

APPENDIX: PROOFS OF PROPOSITION 1 AND PROPOSITION 2

We take two steps to solve the problems P^p and P^a . The first step is to derive the optimal incentive mechanism under the simplified assumption that the agents' individual effort levels are perfectly observable. The solutions to P^p and P^a are then derived constructively in step 2.

Step 1. If the effort level of each agent is observable, hence enforceable, the incentive mechanisms need not depend on x because of the deterministic relationship between x and e . Thus we only need to consider incentive compatible mechanisms in the form of $(S(\theta), e(\theta))$, where $e(\theta)$ is enforceable, which satisfy the incentive compatibility condition

$$\theta^i \in \arg \max_{\hat{\theta}^i} \pi^i(\hat{\theta}^i, \theta^i) \stackrel{\text{def}}{=} E_{\theta^{-i}}[S^i(\hat{\theta}^i, \theta^{-i}) - V^i(e^i(\hat{\theta}^i, \theta^{-i}), \theta^i)],$$

$$\forall \theta^i \in \Theta^i, i \in N. \quad (23)$$

The principal-owner's problem is reduced to P^{pA} :

$$\max_{S, e} E_{\theta}[x(e(\theta)) - \sum_i S^i(\theta)], \quad (24)$$

subject to (23) and (3).

And the collective-owners' problem is reduced to P^{aA} :

$$\max_{S, e} E_{\theta}[x(e(\theta)) - \sum_i V^i(e^i(\theta), \theta^i)], \quad (25)$$

subject to (23), (3), and (5). Note that in (25) the budget balancing condition (5) has been plugged into the objective function (7).

We limit our attention to the differentiable solutions to P^{pA} and P^{aA} . Given a mechanism $[S(\theta), e(\theta)]$, the first-order condition implied by (23) is

$$\pi_{\hat{\theta}^i}^i(\hat{\theta}^i, \theta^i)|_{\hat{\theta}^i=\theta^i} = \int_{\Theta^{-i}} [S_{\hat{\theta}^i}^i(\theta) - V_e^i(e^i(\theta), \theta^i)e_{\hat{\theta}^i}^i] dF^{-i}(\theta^{-i}) = 0$$

$$\forall \theta^i \in \Theta^i, i \in N. \quad (26)$$

By the Envelope Theorem, this implies³³

$$\pi''(\theta^i) = - \int_{\Theta^{-i}} V_{\theta^i}^i(e^i(\theta), \theta^i) dF^{-i}(\theta^{-i}), \quad \forall \theta^i \in \Theta^i, i \in N. \quad (27)$$

Condition (26) also implies $\pi_{\theta^i \theta^i}^i = \int_{\Theta^{-i}} V_{\theta^i \theta^i}^i e_{\theta^i}^i dF^{-i}$ evaluated at $\hat{\theta}^i = \theta^i$. Thus $e_{\theta^i}^i(\theta) \geq 0$ with (27) is a sufficient condition for (23) to be satisfied with a differentiable mechanism (recall that $V_{\theta^i}^i < 0$).

All the above analysis is suitable for both problems of \mathbf{P}^{PA} and \mathbf{P}^{AA} . Now we concentrate on solving \mathbf{P}^{PA} .

Since condition (27) implies that the agents' optimal utility is an increasing function of their type, and the principal's utility is negatively correlated with S , hence with π , the individual rationality constraints can be replaced by

$$\pi^i(\underline{\theta}^i) = 0, \quad \forall i \in N. \quad (28)$$

In what follows we first neglect the requirement $e_{\theta^i}^i(\theta) \geq 0$ and solve the following adverse selection problem:

\mathbf{P}^{AS} :

$$\max_{\pi, e} \int_{\Theta} [x(e(\theta)) - \sum_i [\pi^i(\theta^i) + V^i(e^i(\theta), \theta^i)]] dF(\theta), \quad (29)$$

subject to (27) and (28). Note that from (3), (29) is equivalent to (24). Then we check that the solution to \mathbf{P}^{AS} satisfies $e_{\theta^i}^i(\theta) \geq 0$ for all $i \in N$ and derive the optimal contract for \mathbf{P}^{PA} from (3).

LEMMA 1. *Under A1–A3, there exists a unique optimal solution to \mathbf{P}^{AS} . Denote it by $(\tilde{\pi}(\theta), \tilde{e}(\theta)) = [(\tilde{\pi}^1(\theta^1), \tilde{e}^1(\theta)), \dots, (\tilde{\pi}^n(\theta^n), \tilde{e}^n(\theta))]$. It satisfies (14) and (16).*

Proof. (i) *Existence and Uniqueness.* Let $G(\theta, \pi, e) = x(e) - \sum_i [\pi^i + V^i(e^i, \theta^i)]$ and let $k^i(\theta^i) = (1 - F^i(\theta^i))/f^i(\theta^i)$, and consider the maximization problem

$$\max_e [G(\theta, \pi, e) + \sum_i \pi^i + \sum_i k^i V_{\theta^i}^i(e^i, \theta^i)] \quad (30)$$

for specific values of θ and π . Note that $\sum_i \pi^i$ is cancelled out, hence the solution to the problem should not depend on π . We need this construction for latter use in the proof of sufficiency.

³³ π'' denotes the derivative with respect to θ^i viewing π^i as a compound function of θ^i ; $\pi_{\theta^i}^i$ denotes the partial derivative with respect only to θ^i explicitly appearing in π^i (not those via other variables). The same rule applies to other variables.

From A2 and A3, and the fact that x is concave and $V^i(e^i, \theta^i) - (1 - F^i(\theta^i))/f^i(\theta^i)V_\theta^i(e^i, \theta^i)$ is convex in e for all $\theta \in \Theta$ and $i \in N$, the objective function in (30) is concave and continuously differentiable in e on $[0, B]$, therefore a maximum exists. Further from A1 the maximum must be attained at a unique interior point of $[0, B]$ for each given θ , and satisfies the first-order condition (14). Denote this solution by $\tilde{e}(\theta)$. From the Implicit Function Theorem, $\tilde{e}:\Theta \rightarrow A^n$ is differentiable on Θ under assumptions A1–A3 and the twice differentiability of x . It is then easy to see that given $\tilde{e}(\theta)$, (27) and (28) determine a unique $\tilde{\pi}(\theta)$, which is given by (16).

(ii) *Sufficiency*. Now choose a pair of functions $(\pi(\theta), e(\theta))$ different from $(\tilde{\pi}(\theta), \tilde{e}(\theta))$ which also satisfies conditions (27) and (28). We compare the principal's expected welfare in $(\tilde{\pi}(\theta), \tilde{e}(\theta))$ with his expected welfare in $(\pi(\theta), e(\theta))$. Denote them by \tilde{W} and W , respectively:

$$\begin{aligned}\Delta &= \tilde{W} - W \\ &= \int_{\Theta} [G(\theta, \tilde{\pi}, \tilde{e}) - G(\theta, \pi, e)] dF(\theta) \\ &= \int_{\Theta} [[G(\theta, \tilde{\pi}, \tilde{e}) + \sum_i \tilde{\pi}^i + \sum_i k^i V_\theta^i(\tilde{e}^i, \theta^i)] \\ &\quad - [G(\theta, \pi, e) + \sum_i \pi^i + \sum_i k^i V_\theta^i(e^i, \theta^i)] \\ &\quad - \sum_i k^i V_\theta^i(\tilde{e}^i, \theta^i) + \sum_i k^i V_\theta^i(e^i, \theta^i) - \sum_i (\tilde{\pi}^i - \pi^i)] dF(\theta) \\ &> \int_{\Theta} [\sum_i k^i V_\theta^i(e^i, \theta^i) - \sum_i k^i V_\theta^i(\tilde{e}^i, \theta^i) - \sum_i (\tilde{\pi}^i - \pi^i)] dF(\theta).\end{aligned}$$

Integrating by parts and using (27) and (28) we can derive

$$\begin{aligned}\int_{\Theta} \sum_i (\tilde{\pi}^i - \pi^i) dF(\theta) &= \sum_i \int_{\Theta^i} [\tilde{\pi}(\theta^i) - \pi(\theta^i)] dF^i(\theta^i) \\ &= \sum_i \int_{\Theta^i} [F^i(\theta^i) - 1] \int_{\Theta^{-i}} [V_\theta^i(e^i(\theta), \theta^i) - V_\theta^i(\tilde{e}^i(\theta), \theta^i)] dF^{-i}(\theta^{-i}) d\theta^i \\ &= \int_{\Theta} \sum_i [k^i V_\theta^i(e^i, \theta^i) - k^i V_\theta^i(\tilde{e}^i, \theta^i)] dF(\theta).\end{aligned}$$

Thus $\Delta > 0$.

Q.E.D.

For deriving a solution to P^{PA} , it remains to check whether the second-order condition for the incentive compatibility constraint (23), i.e., $\tilde{e}_{\theta^i}^i \geq 0$,

is satisfied. Let $L = (L^1, \dots, L^n)$ where L^i denote the left-hand-side of Eq. (14). Now differentiating (14) w.r.t. θ for all $i \in N$ yields the matrix relation

$$\frac{dL}{de} \frac{d\tilde{e}}{d\theta} + \frac{dL}{d\theta} = 0, \quad (31)$$

where

$$\begin{aligned} \frac{dL}{de} &= \begin{pmatrix} L_{e^1}^1 & L_{e^2}^1 & \cdots & L_{e^n}^1 \\ L_{e^1}^2 & L_{e^2}^2 & \cdots & L_{e^n}^2 \\ \vdots & \vdots & \ddots & \vdots \\ L_{e^1}^n & L_{e^2}^n & \cdots & L_{e^n}^n \end{pmatrix}, \\ \frac{d\tilde{e}}{d\theta} &= \begin{pmatrix} \tilde{e}_{\theta^1}^1 & \tilde{e}_{\theta^2}^1 & \cdots & \tilde{e}_{\theta^n}^1 \\ \tilde{e}_{\theta^1}^2 & \tilde{e}_{\theta^2}^2 & \cdots & \tilde{e}_{\theta^n}^2 \\ \vdots & \vdots & \ddots & \vdots \\ \tilde{e}_{\theta^1}^n & \tilde{e}_{\theta^2}^n & \cdots & \tilde{e}_{\theta^n}^n \end{pmatrix}, \end{aligned}$$

and

$$\frac{dL}{d\theta} = \begin{pmatrix} L_{\theta^1}^1 & 0 & \cdots & 0 \\ 0 & L_{\theta^2}^2 & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & L_{\theta^n}^n \end{pmatrix}.$$

In fact the matrix dL/de is nothing but the second derivative of G as defined in the proof of Lemma 1 with respect to e . We have shown that G attains an interior maximum at $\tilde{e}(\theta)$ for all the values of $\theta \in \Theta$. This implies that $dL/de = G_{ee}$ is negative definite at $\tilde{e}(\theta)$ for all $\theta \in \Theta$ (see, e.g., Binmore, 1982, Theorems 19.42–43). Consequently, the inverse of matrix $[dL/de]$, $[dL/de]^{-1}$, is negative definite. By rearranging terms in (31) we obtain

$$\frac{d\tilde{e}}{d\theta} = - \left[\frac{dL}{de} \right]^{-1} \frac{dL}{d\theta}. \quad (32)$$

Clearly, the right-hand-side of (32) is a positive definite matrix ($L_{\theta^i}^i = (k^{i'} - 1)V_{e\theta}^i + k^i V_{e\theta\theta}^i > 0$). Thus the matrix $d\tilde{e}/d\theta$ must be positive definite. But this implies that the diagonal entries of $d\tilde{e}/d\theta$, i.e., $\tilde{e}_{\theta^i}^i$, $i \in N$, are all positive.

Finally, from the definition of π^i in (3) we can derive the optimal contract for $\mathbf{P}^{\mathbf{PA}}$: $\tilde{S}(\theta^i) = \tilde{\pi}(\theta^i) + V^i(\tilde{e}^i(\theta), \theta^i)$ [see (15)]. To summarize, we state the result in the following lemma.

LEMMA 2. Under A1–A3, there exists an optimal solution to \mathbf{P}^{PA} , which is characterized by (14), (16), and (15).

We now turn to solving problem \mathbf{P}^{AA} .

LEMMA 3. Under A1, there exists an optimal solution to \mathbf{P}^{AA} . Denote this solution by $(S^*(\theta), e^*(\theta))$. It satisfies (18)–(22).

Proof. (i) *Existence.* By the concavity of x and the convexity of V^i , and by assumption A1, $e^{*i}(\theta)$, $i \in N$, is uniquely determined from (18). Consequently $\pi^{*i}(\theta^i)$ is given by (20) (with suitably chosen α^i), and $S^{*i}(\theta^i)$ by (19). In the statement of this proposition, α^i should all be nonnegative and the sum of them ensures the budget-balancing constraint (22). This is possible if and only if the optimal output exceeds the sum of the agents' information rents. By (19), (20), and (22), the difference between the optimal output and the sum of the agents' information rents equals $\sum_i \alpha^i$. Under assumption A1 (ii) we can show that this difference is indeed positive:

$$\begin{aligned} \sum_i \alpha^i &= \int_{\Theta} [x(e^*(\theta)) - \sum_i (S^{*i} - \alpha^i)] dF(\theta) \\ &= \int_{\Theta} [x(e^*(\theta)) - \sum_i (\pi^{*i}(\theta^i) + V^i(e^{*i}(\theta), \theta^i) - \alpha^i)] dF(\theta) \\ &= \int_{\Theta} \left[x(e^*(\theta)) + \sum_i \left[\frac{1 - F^i(\theta^i)}{f^i(\theta^i)} V_{\theta^i}^i(e^{*i}(\theta), \theta^i) - V^i(e^{*i}(\theta), \theta^i) \right] \right] dF(\theta) \\ &> 0 \quad [\text{by A1 (ii)}]. \end{aligned}$$

It remains to check now if the constraints in \mathbf{P}^{AA} are satisfied. $\pi^{*i}(\theta^i)$ obviously is nonnegative given that $\alpha^i \geq 0$, and from the preceding analysis it has been shown that the incentive compatibility condition (23) is equivalent to (27) plus the second-order condition $e_{\theta^i}^{*i} > 0$. Equation (27) is obviously satisfied if we differentiate $\pi^{*i}(\theta^i)$. We omit the proof of $e_{\theta^i}^{*i} > 0$ because it is analogous to the proof of Lemma 2. Thus the existence of $(S^*(\theta), e^*(\theta))$ is proved.

(ii) *Sufficiency.* Let $G(\theta, e) = x(e) - \sum_i V^i(e^i, \theta^i)$ be the integrand of the objective functional in \mathbf{P}^{AA} . It is clear that $e^*(\theta) = (e^{*1}(\theta), \dots, e^{*n}(\theta))$ is the solution to problem

$$\max_e G(\theta, e)$$

for specific values of θ . This implies that for any other function $e(\theta)$, $G(\theta, e^*(\theta)) \geq G(\theta, e(\theta))$ for all $\theta \in \Theta$. Thus

$$\int_{\Theta^{-i}} G(\theta, e^*(\theta)) dF^{-i} \geq \int_{\Theta^{-i}} G(\theta, e(\theta)) dF^{-i}.$$

Q.E.D.

Step 2. Now we resume the assumption that the agents' individual effort levels are not observable. Since the remaining proofs of Proposition 1 and Proposition 2 are quite similar, we only complete the proof of Proposition 1.

Given (S^p, e^p) as is defined in (13), let $\pi^i(\hat{\theta}^i, e^i, \theta^i)$ be the expected utility of agent i reporting $\hat{\theta}^i$ and choosing effort e^i when the other agents play the ICP equilibrium strategies. Let $\bar{\pi}^i(\hat{\theta}^i, e^i, \theta)$ denote the i th agent's utility whose type is θ^i and who has announced $\hat{\theta}^i$, after the stage of communication when the other agents have announced θ^{-i} and are expected to follow the mediator's recommended effort levels. $\bar{\pi}^i(\hat{\theta}^i, e^i, \theta)$ writes as

$$\begin{aligned} \bar{\pi}^i(\hat{\theta}^i, e^i, \theta) &= \tilde{S}^i(\hat{\theta}^i, \theta^{-i}) \\ &\quad + D^i(\hat{\theta}^i, \theta^{-i})[x(e^i, \tilde{e}^{-i}(\hat{\theta}^i, \theta^{-i})) - x(\tilde{e}(\hat{\theta}^i, \theta^{-i}))] - V(e^i, \theta^i) \end{aligned}$$

and $\pi^i(\hat{\theta}^i, e^i, \theta^i)$ writes as

$$\pi^i(\hat{\theta}^i, e^i, \theta^i) = \int_{\Theta^{-i}} \bar{\pi}^i(\hat{\theta}^i, e^i, \theta) dF^{-i}. \quad (33)$$

We first verify that in (S^p, e^p) agent i will always choose the recommended effort level irrespective of his report, i.e., $e^i = \tilde{e}^i(\hat{\theta}^i, \theta^{-i})$. The first and second-order conditions for e^i to maximize (33) are

$$\bar{\pi}_{e^i}^i(\hat{\theta}^i, e^i, \theta) = D^i(\hat{\theta}^i, \theta^{-i})x_{e^i} - V_{e^i}(e^i, \theta^i) = 0, \quad (34)$$

for all $\hat{\theta}^i \in \Theta^i$, $\theta \in \Theta$, and $i \in N$, and

$$\bar{\pi}_{e^i e^i}^i = D^i x_{e^i e^i} - V_{e^i e^i} \leq 0 \quad (35)$$

for all $\hat{\theta}^i \in \Theta^i$, $\theta \in \Theta$, and $i \in N$. Equation (34) is obviously satisfied for $e^i = \tilde{e}^i(\hat{\theta}^i, \theta^{-i})$ given the construction of D^i , and (35) is always satisfied. This is sufficient to guarantee that the recommended effort will be chosen.

When all the agents choose the recommended effort levels, (S^p, e^p) practically reduces to (\tilde{S}, \tilde{e}) . From Lemma 2 (\tilde{S}, \tilde{e}) induces all the agents to report truthfully. Thus (S^p, e^p) achieves an ICP equilibrium [See (1) and (2)]. When all the agents play the equilibrium strategies, their individual rationality constraints are clearly satisfied, and the principal obtains the expected utility as though the agents' effort could be enforced. This implies that (S^p, e^p) is optimal to \mathbf{P}^p . Q.E.D.

REFERENCES

- Alchian, Armen A., and Demsetz, Harold, "Production, Information Costs, and Economic Organization." *Amer. Econom. Rev.* **62**, 5:777-795, Dec. 1972.
- d'Aspremont, Claude, and Gérard-Varet, Louis-André, "Incentives and Incomplete Information." *J. Public Econom.* **11**, 1:25-45, Feb. 1979.
- Baron, David, and Besanko, David, "Regulation and Information in a Continuing Relationship." *Inform. Econom. Policy* **1**, 267-302, 1984.
- Baron, David, and Myerson, Roger, "Regulating a Monopolist with Unknown Costs." *Econometrica* **50**, 4:911-930, July 1982.
- Berle, Adolf A., Jr., and Means, Gardiner C., *The Modern Corporation and Private Property*. New York: MacMillan, 1932.
- Binmore, K. G., *Mathematical Analysis*. 2nd ed. Cambridge: Cambridge Univ. Press, 1982.
- Bonin, John P., and Putterman, Louis G., *Economics of Co-operation and the Labor-Managed Economy*. London: Harwood, 1987.
- Boyd, John H., Prescott, Edward C., and Smith, Bruce D., "Organizations in Economic Analysis." *Canad. J. Econom.* **21**, 3:477-491, Aug. 1988.
- Dasgupta, Partha, Hammond, Peter, and Maskin, Eric, "The Implementation of Social Choice Rules: Some General Results on Incentive Compatibility." *Rev. Econom. Stud.* **46**, 2:185-216, 1979.
- Demski, Joel S., and Sappington, David E., "Optimal Incentive Contracts with Multiple Agents." *J. Econom. Theory* **33**, 1:152-171, 1984.
- Demski, Joel S., Sappington, David E., and Spiller, Pablo T., "Incentive Schemes with Multiple Agents and Bankruptcy Constraints." *J. Econom. Theory* **44**, 1:156-167, 1988.
- Estrin, Saul, "Some Reflections on Self-management, Social Choice, and Reform in Eastern Europe." *J. Comp. Econom.* **15**, 2:349-366, June 1991.
- Eswaran, Mukesh, and Kotwal, Ashok, "The Moral Hazard of Budget-breaking." *Rand J. Econom.* **15**, 4:578-581, Winter 1984.
- Forges, Françoise, "An Approach to Communication Equilibria." *Econometrica* **54**, 6:1375-1385, Nov. 1986.
- Gintis, Herbert, "Financial Markets and the Political Structure of the Enterprise." *J. Econom. Behav. Organ.* **11**, 3:311-322, May 1989.
- Groves, Theodore, and Ledyard, John, "Optimal Allocation of Public Goods: A Solution to the Free-Rider Problem." *Econometrica* **45**, 4:783-809, May 1977.
- Grossman, Sanford J., and Hart, Oliver D., "The Costs and Benefits of Ownership: A Theory of Vertical and Lateral Integration." *J. Polit. Econom.* **94**, 4:691-719, 1986.
- Guesnerie, Roger, and Laffont, Jean-Jacques, "A Complete Solution to a Class of Principal-Agent Problems with an Application to the Control of a Self-Managed Firm." *J. Public Econom.* **25**, 3:329-369, Dec. 1984.
- Guesnerie, Roger, Picard, Pierre, and Rey, Patrick, "Adverse Selection and Moral Hazard with Risk Neutral Agents." *European Econom. Rev.* **33**, 4:807-823, May 1989.
- Hart, Oliver D., "Capital Structure as a Control Mechanism in Corporations." *Canad. J. Econom.* **21**, 3:467-476, Aug. 1988.
- Hart, Oliver, and Holmström, Bengt, "The Theory of Contracts." In T. Bewley, Ed., *Advances in Economic Theory*. Cambridge: Cambridge Univ. Press, 1987.
- Hart, Oliver, and Moore, John, "Property Rights and the Nature of the Firm." Discussion Paper, No. TE/88/174. London School of Economics, 1988.
- Holmström, Bengt, "Moral Hazard in Teams." *Bell J. Econom.* **13**, 324-340, 1982.
- Holmström, Bengt, and Myerson, Roger, "Efficient and Durable Decision Rules with Incomplete Information." *Econometrica* **51**, 6:1799-1820, Nov. 1983.
- Holmström, Bengt, and Tirole, Jean, "The Theory of the Firm." In R. Schmalensee and R.

- Willig, Eds., *Handbook of Industrial Organization, Volume I*. Amsterdam: Elsevier, 1987.
- Horvat, Branko, *The Political Economy of Socialism*. Oxford: Martin Robertson, 1982.
- Jensen, Michael C., and Meckling, William H., "Theory of the Firm: Managerial Behavior, Agency Costs and Ownership Structure." *J. Finan. Econom.* 3, 305-360, 1976.
- Jensen, Michael C., and Meckling, William H., "Rights and Production Functions: An Application to Labor-Managed Firms and Codetermination." *J. Business* 52, 4:469-506, Oct. 1979.
- Jones, Derek C., and Svejnar, Jan (Eds.), *Participatory and Self-Managed Firms: Evaluating Economic Performance*. Lexington, Mass.: Heath, 1982.
- Laffont, Jean-Jacques, and Tirole, Jean, "Using Cost Observation to Regulate Firms." *J. Polit. Econom.* 94, 3:614-641, 1986.
- Ma, Ching-To, Moore, John, and Turnbull, Stephen, "Stopping Agents from 'Cheating'." *J. Econom. Theory* 46, 2:355-372, Dec. 1988.
- MacLeod, B., "Behavior and the Organization of the Firm." *J. Comp. Econom.* 11, 2:207-220, June 1987.
- MacLeod, Bentley, "Equity, Efficiency, and Incentives in Cooperative Teams." In Derek C. Jones and Jan Svejnar, Eds., *Advances in the Economic Analysis of Participatory and Labor-Managed Firms*, Vol. 3, pp. 5-23. London: JAI Press, Inc., 1988.
- Martin, Robert E., "Profit Sharing, Uncertainty and the Enterprise Contract." *Anal. Public Co-op. Econom.* 62, 1:81-101, Jan/Mar. 1991.
- Maskin, Eric, and Riley, John, "Monopoly with Incomplete Information." *Rand J. Econom.* 15, 2:171-196, Summer 1984.
- McAfee, R. Preston, and McMillan, John, "Auctions and Bidding." *J. Econom. Lit.* 25, 699-738, June 1987.
- McAfee, R. Preston, and McMillan, John, "Optimal Contracts for Teams." *Internat. Econom. Rev.* 32, 3:561-577, Aug. 1991.
- Milgrom, Paul, and Roberts, John, "Bargaining Costs, Influence Costs and the Organization of Economic Activity." In J. Alt and K. Shepsle, Eds., *The Foundations of Political Economy*. Cambridge: Harvard Univ. Press, 1989.
- Miyazaki, Hajime, "The Rat Race and Internal Labour Markets." *Bell J. Econom.* 8, 394-418, 1977.
- Miyazaki, Hajime, "On Success and Dissolution of the Labor-Managed Firm in the Capitalist Economy." *J. Polit. Econom.* 92, 5:909-931, 1984.
- Myerson, Roger B., "Optimal Coordination Mechanisms in Generalized Principal-Agent Problems." *J. Math. Econom.* 10, 1:67-81, 1982.
- Myerson, Roger B., "Cooperative Games with Incomplete Information." *Internat. J. Game Theory* 13, 2:69-96, 1984.
- Myerson, Roger B., "Multistage Games with Communication." *Econometrica* 54, 2:323-358, Mar. 1986.
- Palfrey, Thomas R., "Implementation in Bayesian Equilibrium." Working Paper, California Institute of Technology, 1991.
- Picard, Pierre, "On the Design of Incentive Schemes under Moral Hazard and Adverse Selection." *J. Public Econom.* 33, 33:305-331, Aug. 1987.
- Picard, Pierre, and Rey, Patrick, "Incentives in Cooperative Research and Development." In Champsaur et al., Eds., *Essays in Honor of Edmond Malinvaud*, pp. 252-279. Cambridge: MIT Press, 1990.
- Pint, Ellen M., "Nationalization vs. Regulation of Monopolies: The Effects of Ownership on Efficiency." *J. Public Econom.* 44, 2:131-164, Mar. 1991.
- Putterman, Louis, "Some Behavioral Perspective on the Dominance of Hierarchical over Democratic Forms of Enterprise." *J. Econom. Behav. Organ.* 3, 2:139-160, 1982.

- Putterman, Louis, and Skillman, Gil, Jr., "The Incentive Effects of Monitoring under Alternative Compensation Schemes." *Internat. J. Ind. Organ.* 6, 1:109-119, Mar. 1988.
- Rasmusen, Eric, "Moral Hazard in Risk-Averse Teams." *Rand J. Econom.* 18, 3:429-435, Autumn 1987.
- Roemer, John, E., and Silvestre, Joaquim, "A Welfare Comparison of Private and Public Monopoly." Working Paper Series No. 340, University of California, Davis, 1989.
- Sen, Amartya K., "Labor Allocation in a Cooperative Enterprise." *Rev. Econom. Stud.* 33, 2:361-371, 1966.
- Stephen, Frank G. (Ed.), *Performance of Labor-Managed Firms*. London: MacMillan, 1982.
- Stiglitz, Joseph E., "Incentives and Risk Sharing in Share-Cropping." *Rev. Econom. Stud.* 41, 2:219-255, 1974.
- Tapiero, Charles S., "The Utility of Manufacturing Cooperatives." *J. Econom. Dynamics Control* 13, 4:471-483, Oct. 1989.
- Tirole, Jean, "The Multicontract Organization." *Canad. J. Econom.* 21, 3:459-466, Aug. 1988.
- Williamson, Oliver, "Corporate Governance." *Yale Law J.* 93, 5:1197-1230, Apr. 1984.
- Wilson, Robert, "Efficient Trading." In George R. Feiwel, Ed., *Issues in Contemporary Microeconomics*. New York: McMillan, 1983.
- Zou, Liang, "Ownership Structure and Efficiency: An Incentive Mechanism Approach." CentER Discussion Paper No. 8955, Tilburg University, The Netherlands, 1989.
- Zou, Liang, "Notes on the Working of Coordination Mechanisms under Communication Constraints." Mimeo, University of Limburg, The Netherlands, 1991.
- Zou, Liang, "Threat-based Incentive Mechanisms under Moral Hazard and Adverse Selection." *J. Comp. Econom.* 16, 1:47-74, Mar. 1992.

- No. 1 G. Marini and F. van der Ploeg, Monetary and fiscal policy in an optimising model with capital accumulation and finite lives, *The Economic Journal*, vol. 98, no. 392, 1988, pp. 772 - 786.
- No. 2 F. van der Ploeg, International policy coordination in interdependent monetary economies, *Journal of International Economics*, vol. 25, 1988, pp. 1 - 23.
- No. 3 A.P. Barten, The history of Dutch macroeconomic modelling (1936-1986), in W. Driehuis, M.M.G. Fase and H. den Hartog (eds.), *Challenges for Macroeconomic Modelling*, Contributions to Economic Analysis 178, Amsterdam: North-Holland, 1988, pp. 39 - 88.
- No. 4 F. van der Ploeg, Disposable income, unemployment, inflation and state spending in a dynamic political-economic model, *Public Choice*, vol. 60, 1989, pp. 211 - 239.
- No. 5 Th. ten Raa and F. van der Ploeg, A statistical approach to the problem of negatives in input-output analysis, *Economic Modelling*, vol. 6, no. 1, 1989, pp. 2 - 19.
- No. 6 E. van Damme, Renegotiation-proof equilibria in repeated prisoners' dilemma, *Journal of Economic Theory*, vol. 47, no. 1, 1989, pp. 206 - 217.
- No. 7 C. Mulder and F. van der Ploeg, Trade unions, investment and employment in a small open economy: a Dutch perspective, in J. Muysken and C. de Neubourg (eds.), *Unemployment in Europe*, London: The Macmillan Press Ltd, 1989, pp. 200 - 229.
- No. 8 Th. van de Klundert and F. van der Ploeg, Wage rigidity and capital mobility in an optimizing model of a small open economy, *De Economist*, vol. 137, nr. 1, 1989, pp. 47 - 75.
- No. 9 G. Dhaene and A.P. Barten, When it all began: the 1936 Tinbergen model revisited, *Economic Modelling*, vol. 6, no. 2, 1989, pp. 203 - 219.
- No. 10 F. van der Ploeg and A.J. de Zeeuw, Conflict over arms accumulation in market and command economies, in F. van der Ploeg and A.J. de Zeeuw (eds.), *Dynamic Policy Games in Economics*, Contributions to Economic Analysis 181, Amsterdam: Elsevier Science Publishers B.V. (North-Holland), 1989, pp. 91 - 119.
- No. 11 J. Driffill, Macroeconomic policy games with incomplete information: some extensions, in F. van der Ploeg and A.J. de Zeeuw (eds.), *Dynamic Policy Games in Economics*, Contributions to Economic Analysis 181, Amsterdam: Elsevier Science Publishers B.V. (North-Holland), 1989, pp. 289 - 322.
- No. 12 F. van der Ploeg, Towards monetary integration in Europe, in P. De Grauwe et al., *De Europese Monetair Integratie: vier visies*, Wetenschappelijke Raad voor het Regeringsbeleid V 66, 's-Gravenhage: SDU uitgeverij, 1989, pp. 81 - 106.

- No. 13 R.J.M. Alessie and A. Kapteyn, Consumption, savings and demography, in A. Wenig, K.F. Zimmermann (eds.), *Demographic Change and Economic Development*, Berlin/Heidelberg: Springer-Verlag, 1989, pp. 272 - 305.
- No. 14 A. Hoque, J.R. Magnus and B. Pesaran, The exact multi-period mean-square forecast error for the first-order autoregressive model, *Journal of Econometrics*, vol. 39, no. 3, 1988, pp. 327 - 346.
- No. 15 R. Alessie, A. Kapteyn and B. Melenberg, The effects of liquidity constraints on consumption: estimation from household panel data, *European Economic Review*, vol. 33, no. 2/3, 1989, pp. 547 - 555.
- No. 16 A. Holly and J.R. Magnus, A note on instrumental variables and maximum likelihood estimation procedures, *Annales d'Économie et de Statistique*, no. 10, April-June, 1988, pp. 121 - 138.
- No. 17 P. ten Hacken, A. Kapteyn and I. Woittiez, Unemployment benefits and the labor market, a micro/macro approach, in B.A. Gustafsson and N. Anders Klevmarken (eds.), *The Political Economy of Social Security*, Contributions to Economic Analysis 179, Amsterdam: Elsevier Science Publishers B.V. (North-Holland), 1989, pp. 143 - 164.
- No. 18 T. Wansbeek and A. Kapteyn, Estimation of the error-components model with incomplete panels, *Journal of Econometrics*, vol. 41, no. 3, 1989, pp. 341 - 361.
- No. 19 A. Kapteyn, P. Kooreman and R. Willemse, Some methodological issues in the implementation of subjective poverty definitions, *The Journal of Human Resources*, vol. 23, no. 2, 1988, pp. 222 - 242.
- No. 20 Th. van de Klundert and F. van der Ploeg, Fiscal policy and finite lives in interdependent economies with real and nominal wage rigidity, *Oxford Economic Papers*, vol. 41, no. 3, 1989, pp. 459 - 489.
- No. 21 J.R. Magnus and B. Pesaran, The exact multi-period mean-square forecast error for the first-order autoregressive model with an intercept, *Journal of Econometrics*, vol. 42, no. 2, 1989, pp. 157 - 179.
- No. 22 F. van der Ploeg, Two essays on political economy: (i) The political economy of overvaluation, *The Economic Journal*, vol. 99, no. 397, 1989, pp. 850 - 855; (ii) Election outcomes and the stockmarket, *European Journal of Political Economy*, vol. 5, no. 1, 1989, pp. 21 - 30.
- No. 23 J.R. Magnus and A.D. Woodland, On the maximum likelihood estimation of multivariate regression models containing serially correlated error components, *International Economic Review*, vol. 29, no. 4, 1988, pp. 707 - 725.
- No. 24 A.J.J. Talman and Y. Yamamoto, A simplicial algorithm for stationary point problems on polytopes, *Mathematics of Operations Research*, vol. 14, no. 3, 1989, pp. 383 - 399.
- No. 25 E. van Damme, Stable equilibria and forward induction, *Journal of Economic Theory*, vol. 48, no. 2, 1989, pp. 476 - 496.

- No. 26 A.P. Barten and L.J. Bettendorf, Price formation of fish: An application of an inverse demand system, *European Economic Review*, vol. 33, no. 8, 1989, pp. 1509 - 1525.
- No. 27 G. Noldeke and E. van Damme, Signalling in a dynamic labour market, *Review of Economic Studies*, vol. 57 (1), no. 189, 1990, pp. 1 - 23.
- No. 28 P. Kop Jansen and Th. ten Raa, The choice of model in the construction of input-output coefficients matrices, *International Economic Review*, vol. 31, no. 1, 1990, pp. 213 - 227.
- No. 29 F. van der Ploeg and A.J. de Zeeuw, Perfect equilibrium in a model of competitive arms accumulation, *International Economic Review*, vol. 31, no. 1, 1990, pp. 131 - 146.
- No. 30 J.R. Magnus and A.D. Woodland, Separability and aggregation, *Economica*, vol. 57, no. 226, 1990, pp. 239 - 247.
- No. 31 F. van der Ploeg, International interdependence and policy coordination in economies with real and nominal wage rigidity, *Greek Economic Review*, vol. 10, no. 1, June 1988, pp. 1 - 48.
- No. 32 E. van Damme, Signaling and forward induction in a market entry context, *Operations Research Proceedings 1989*, Berlin-Heidelberg: Springer-Verlag, 1990, pp. 45 - 59.
- No. 33 A.P. Barten, Toward a levels version of the Rotterdam and related demand systems, *Contributions to Operations Research and Economics*, Cambridge: MIT Press, 1989, pp. 441 - 465.
- No. 34 F. van der Ploeg, International coordination of monetary policies under alternative exchange-rate regimes, in F. van der Ploeg (ed.), *Advanced Lectures in Quantitative Economics*, London-Orlando: Academic Press Ltd., 1990, pp. 91 - 121.
- No. 35 Th. van de Klundert, On socioeconomic causes of 'wait unemployment', *European Economic Review*, vol. 34, no. 5, 1990, pp. 1011 - 1022.
- No. 36 R.J.M. Alessie, A. Kapteyn, J.B. van Lochem and T.J. Wansbeek, Individual effects in utility consistent models of demand, in J. Hartog, G. Ridder and J. Theeuwes (eds.), *Panel Data and Labor Market Studies*, Amsterdam: Elsevier Science Publishers B.V. (North-Holland), 1990, pp. 253 - 278.
- No. 37 F. van der Ploeg, Capital accumulation, inflation and long-run conflict in international objectives, *Oxford Economic Papers*, vol. 42, no. 3, 1990, pp. 501 - 525.
- No. 38 Th. Nijman and F. Palm, Parameter identification in ARMA Processes in the presence of regular but incomplete sampling, *Journal of Time Series Analysis*, vol. 11, no. 3, 1990, pp. 239 - 248.
- No. 39 Th. van de Klundert, Wage differentials and employment in a two-sector model with a dual labour market, *Metroeconomica*, vol. 40, no. 3, 1989, pp. 235 - 256.

- No. 40 Th. Nijman and M.F.J. Steel, Exclusion restrictions in instrumental variables equations, *Econometric Reviews*, vol. 9, no. 1, 1990, pp. 37 - 55.
- No. 41 A. van Soest, I. Woittiez and A. Kapteyn, Labor supply, income taxes, and hours restrictions in the Netherlands, *Journal of Human Resources*, vol. 25, no. 3, 1990, pp. 517 - 558.
- No. 42 Th.C.M.J. van de Klundert and A.B.T.M. van Schaik, Unemployment persistence and loss of productive capacity: a Keynesian approach, *Journal of Macroeconomics*, vol. 12, no. 3, 1990, pp. 363 - 380.
- No. 43 Th. Nijman and M. Verbeek, Estimation of time-dependent parameters in linear models using cross-sections, panels, or both, *Journal of Econometrics*, vol. 46, no. 3, 1990, pp. 333 - 346.
- No. 44 E. van Damme, R. Selten and E. Winter, Alternating bid bargaining with a smallest money unit, *Games and Economic Behavior*, vol. 2, no. 2, 1990, pp. 188 - 201.
- No. 45 C. Dang, The D_1 -triangulation of \mathbb{R}^n for simplicial algorithms for computing solutions of nonlinear equations, *Mathematics of Operations Research*, vol. 16, no. 1, 1991, pp. 148 - 161.
- No. 46 Th. Nijman and F. Palm, Predictive accuracy gain from disaggregate sampling in ARIMA models, *Journal of Business & Economic Statistics*, vol. 8, no. 4, 1990, pp. 405 - 415.
- No. 47 J.R. Magnus, On certain moments relating to ratios of quadratic forms in normal variables: further results, *Sankhya: The Indian Journal of Statistics*, vol. 52, series B, part. 1, 1990, pp. 1 - 13.
- No. 48 M.F.J. Steel, A Bayesian analysis of simultaneous equation models by combining recursive analytical and numerical approaches, *Journal of Econometrics*, vol. 48, no. 1/2, 1991, pp. 83 - 117.
- No. 49 F. van der Ploeg and C. Withagen, Pollution control and the ramsey problem, *Environmental and Resource Economics*, vol. 1, no. 2, 1991, pp. 215 - 236.
- No. 50 F. van der Ploeg, Money and capital in interdependent economies with overlapping generations, *Economica*, vol. 58, no. 230, 1991, pp. 233 - 256.
- No. 51 A. Kapteyn and A. de Zeeuw, Changing incentives for economic research in the Netherlands, *European Economic Review*, vol. 35, no. 2/3, 1991, pp. 603 - 611.
- No. 52 C.G. de Vries, On the relation between GARCH and stable processes, *Journal of Econometrics*, vol. 48, no. 3, 1991, pp. 313 - 324.
- No. 53 R. Alessie and A. Kapteyn, Habit formation, interdependent preferences and demographic effects in the almost ideal demand system, *The Economic Journal*, vol. 101, no. 406, 1991, pp. 404 - 419.
- No. 54 W. van Groenendaal and A. de Zeeuw, Control, coordination and conflict on international commodity markets, *Economic Modelling*, vol. 8, no. 1, 1991, pp. 90 - 101.

- No. 55 F. van der Ploeg and A.J. Markink, Dynamic policy in linear models with rational expectations of future events: A computer package, *Computer Science in Economics and Management*, vol. 4, no. 3, 1991, pp. 175 - 199.
- No. 56 H.A. Keuzenkamp and F. van der Ploeg, Savings, investment, government finance, and the current account: The Dutch experience, in G. Alogoskoufis, L. Papademos and R. Portes (eds.), *External Constraints on Macroeconomic Policy: The European Experience*, Cambridge: Cambridge University Press, 1991, pp. 219 - 263.
- No. 57 Th. Nijman, M. Verbeek and A. van Soest, The efficiency of rotating-panel designs in an analysis-of-variance model, *Journal of Econometrics*, vol. 49, no. 3, 1991, pp. 373 - 399.
- No. 58 M.F.J. Steel and J.-F. Richard, Bayesian multivariate exogeneity analysis - an application to a UK money demand equation, *Journal of Econometrics*, vol. 49, no. 1/2, 1991, pp. 239 - 274.
- No. 59 Th. Nijman and F. Palm, Generalized least squares estimation of linear models containing rational future expectations, *International Economic Review*, vol. 32, no. 2, 1991, pp. 383 - 389.
- No. 60 E. van Damme, Equilibrium selection in 2×2 games, *Revista Espanola de Economia*, vol. 8, no. 1, 1991, pp. 37 - 52.
- No. 61 E. Bennett and E. van Damme, Demand commitment bargaining: the case of apex games, in R. Selten (ed.), *Game Equilibrium Models III - Strategic Bargaining*, Berlin: Springer-Verlag, 1991, pp. 118 - 140.
- No. 62 W. Güth and E. van Damme, Gorbys games - a game theoretic analysis of disarmament campaigns and the defense efficiency - hypothesis -, in R. Avenhaus, H. Karkar and M. Rudnianski (eds.), *Defense Decision Making - Analytical Support and Crisis Management*, Berlin: Springer-Verlag, 1991, pp. 215 - 240.
- No. 63 A. Roell, Dual-capacity trading and the quality of the market, *Journal of Financial Intermediation*, vol. 1, no. 2, 1990, pp. 105 - 124.
- No. 64 Y. Dai, G. van der Laan, A.J.J. Talman and Y. Yamamoto, A simplicial algorithm for the nonlinear stationary point problem on an unbounded polyhedron, *Siam Journal of Optimization*, vol. 1, no. 2, 1991, pp. 151 - 165.
- No. 65 M. McAleer and C.R. McKenzie, Keynesian and new classical models of unemployment revisited, *The Economic Journal*, vol. 101, no. 406, 1991, pp. 359 - 381.
- No. 66 A.J.J. Talman, General equilibrium programming, *Nieuw Archief voor Wiskunde*, vol. 8, no. 3, 1990, pp. 387 - 397.
- No. 67 J.R. Magnus and B. Pesaran, The bias of forecasts from a first-order autoregression, *Econometric Theory*, vol. 7, no. 2, 1991, pp. 222 - 235.

- No. 68 F. van der Ploeg, Macroeconomic policy coordination issues during the various phases of economic and monetary integration in Europe, *European Economy - The Economics of EMU*, Commission of the European Communities, special edition no. 1, 1991, pp. 136 - 164.
- No. 69 H. Keuzenkamp, A precursor to Muth: Tinbergen's 1932 model of rational expectations, *The Economic Journal*, vol. 101, no. 408, 1991, pp. 1245 - 1253.
- No. 70 L. Zou, The target-incentive system vs. the price-incentive system under adverse selection and the ratchet effect, *Journal of Public Economics*, vol. 46, no. 1, 1991, pp. 51 - 89.
- No. 71 E. Bomhoff, Between price reform and privatization: Eastern Europe in transition, *Finanzmarkt und Portfolio Management*, vol. 5, no. 3, 1991, pp. 241 - 251.
- No. 72 E. Bomhoff, Stability of velocity in the major industrial countries: a Kalman filter approach, *International Monetary Fund Staff Papers*, vol. 38, no. 3, 1991, pp. 626 - 642.
- No. 73 E. Bomhoff, Currency convertibility: when and how? A contribution to the Bulgarian debate, *Kredit und Kapital*, vol. 24, no. 3, 1991, pp. 412 - 431.
- No. 74 H. Keuzenkamp and F. van der Ploeg, Perceived constraints for Dutch unemployment policy, in C. de Neubourg (ed.), *The Art of Full Employment - Unemployment Policy in Open Economies*, Contributions to Economic Analysis 203, Amsterdam: Elsevier Science Publishers B.V. (North-Holland), 1991, pp. 7 - 37.
- No. 75 H. Peters and E. van Damme, Characterizing the Nash and Raiffa bargaining solutions by disagreement point axioms, *Mathematics of Operations Research*, vol. 16, no. 3, 1991, pp. 447 - 461.
- No. 76 P.J. Deschamps, On the estimated variances of regression coefficients in misspecified error components models, *Econometric Theory*, vol. 7, no. 3, 1991, pp. 369 - 384.
- No. 77 A. de Zeeuw, Note on 'Nash and Stackelberg solutions in a differential game model of capitalism', *Journal of Economic Dynamics and Control*, vol. 16, no. 1, 1992, pp. 139 - 145.
- No. 78 J.R. Magnus, On the fundamental bordered matrix of linear estimation, in F. van der Ploeg (ed.), *Advanced Lectures in Quantitative Economics*, London-Orlando: Academic Press Ltd., 1990, pp. 583 - 604.
- No. 79 F. van der Ploeg and A. de Zeeuw, A differential game of international pollution control, *Systems and Control Letters*, vol. 17, no. 6, 1991, pp. 409 - 414.
- No. 80 Th. Nijman and M. Verbeek, The optimal choice of controls and pre-experimental observations, *Journal of Econometrics*, vol. 51, no. 1/2, 1992, pp. 183 - 189.
- No. 81 M. Verbeek and Th. Nijman, Can cohort data be treated as genuine panel data?, *Empirical Economics*, vol. 17, no. 1, 1992, pp. 9 - 23.

- No. 82 E. van Damme and W. Güth, Equilibrium selection in the Spence signaling game, in R. Selten (ed.), *Game Equilibrium Models II - Methods, Morals, and Markets*, Berlin: Springer-Verlag, 1991, pp. 263 - 288.
- No. 83 R.P. Gilles and P.H.M. Ruys, Characterization of economic agents in arbitrary communication structures, *Nieuw Archief voor Wiskunde*, vol. 8, no. 3, 1990, pp. 325 - 345.
- No. 84 A. de Zeeuw and F. van der Ploeg, Difference games and policy evaluation: a conceptual framework, *Oxford Economic Papers*, vol. 43, no. 4, 1991, pp. 612 - 636.
- No. 85 E. van Damme, Fair division under asymmetric information, in R. Selten (ed.), *Rational Interaction - Essays in Honor of John C. Harsanyi*, Berlin/Heidelberg: Springer-Verlag, 1992, pp. 121 - 144.
- No. 86 F. de Jong, A. Kemna and T. Kloek, A contribution to event study methodology with an application to the Dutch stock market, *Journal of Banking and Finance*, vol. 16, no. 1, 1992, pp. 11 - 36.
- No. 87 A.P. Barten, The estimation of mixed demand systems, in R. Bewley and T. Van Hoa (eds.), *Contributions to Consumer Demand and Econometrics, Essays in Honour of Henri Theil*, Basingstoke: The Macmillan Press Ltd., 1992, pp. 31 - 57.
- No. 88 T. Wansbeek and A. Kapteyn, Simple estimators for dynamic panel data models with errors in variables, in R. Bewley and T. Van Hoa (eds.), *Contributions to Consumer Demand and Econometrics, Essays in Honour of Henri Theil*, Basingstoke: The Macmillan Press Ltd., 1992, pp. 238 - 251.
- No. 89 S. Chib, J. Osiewalski and M. Steel, Posterior inference on the degrees of freedom parameter in multivariate-*t* regression models, *Economics Letters*, vol. 37, no. 4, 1991, pp. 391 - 397.
- No. 90 H. Peters and P. Wakker, Independence of irrelevant alternatives and revealed group preferences, *Econometrica*, vol. 59, no. 6, 1991, pp. 1787 - 1801.
- No. 91 G. Alogoskoufis and F. van der Ploeg, On budgetary policies, growth, and external deficits in an interdependent world, *Journal of the Japanese and International Economies*, vol. 5, no. 4, 1991, pp. 305 - 324.
- No. 92 R.P. Gilles, G. Owen and R. van den Brink, Games with permission structures: The conjunctive approach, *International Journal of Game Theory*, vol. 20, no. 3, 1992, pp. 277 - 293.
- No. 93 J.A.M. Potters, I.J. Curiel and S.H. Tijs, Traveling salesman games, *Mathematical Programming*, vol. 53, no. 2, 1992, pp. 199 - 211.
- No. 94 A.P. Jurg, M.J.M. Jansen, J.A.M. Potters and S.H. Tijs, A symmetrization for finite two-person games, *Zeitschrift für Operations Research - Methods and Models of Operations Research*, vol. 36, no. 2, 1992, pp. 111 - 123.

- No. 95 A. van den Nouweland, P. Born and S. Tijs, Allocation rules for hypergraph communication situations, *International Journal of Game Theory*, vol. 20, no. 3, 1992, pp. 255 - 268.
- No. 96 E.J. Bomhoff, Monetary reform in Eastern Europe, *European Economic Review*, vol. 36, no. 2/3, 1992, pp. 454 - 458.
- No. 97 F. van der Ploeg and A. de Zeeuw, International aspects of pollution control, *Environmental and Resource Economics*, vol. 2, no. 2, 1992, pp. 117 - 139.
- No. 98 P.E.M. Borm and S.H. Tijs, Strategic claim games corresponding to an NTU-game, *Games and Economic Behavior*, vol. 4, no. 1, 1992, pp. 58 - 71.
- No. 99 A. van Soest and P. Kooreman, Coherency of the indirect translog demand system with binding nonnegativity constraints, *Journal of Econometrics*, vol. 44, no. 3, 1990, pp. 391 - 400.
- No. 100 Th. ten Raa and E.N. Wolff, Secondary products and the measurement of productivity growth, *Regional Science and Urban Economics*, vol. 21, no. 4, 1991, pp. 581 - 615.
- No. 101 P. Kooreman and A. Kapteyn, On the empirical implementation of some game theoretic models of household labor supply, *The Journal of Human Resources*, vol. 25, no. 4, 1990, pp. 584 - 598.
- No. 102 H. Bester, Bertrand equilibrium in a differentiated duopoly, *International Economic Review*, vol. 33, no. 2, 1992, pp. 433 - 448.
- No. 103 J.A.M. Potters and S.H. Tijs, The nucleolus of a matrix game and other nucleoli, *Mathematics of Operations Research*, vol. 17, no. 1, 1992, pp. 164 - 174.
- No. 104 A. Kapteyn, P. Kooreman and A. van Soest, Quantity rationing and concavity in a flexible household labor supply model, *Review of Economics and Statistics*, vol. 72, no. 1, 1990, pp. 55 - 62.
- No. 105 A. Kapteyn and P. Kooreman, Household labor supply: What kind of data can tell us how many decision makers there are?, *European Economic Review*, vol. 36, no. 2/3, 1992, pp. 365 - 371.
- No. 106 Th. van de Klundert and S. Smulders, Reconstructing growth theory: A survey, *De Economist*, vol. 140, no. 2, 1992, pp. 177 - 203.
- No. 107 N. Rankin, Imperfect competition, expectations and the multiple effects of monetary growth, *The Economic Journal*, vol. 102, no. 413, 1992, pp. 743 - 753.
- No. 108 J. Greenberg, On the sensitivity of von Neumann and Morgenstern abstract stable sets: The stable and the individual stable bargaining set, *International Journal of Game Theory*, vol. 21, no. 1, 1992, pp. 41 - 55.
- No. 109 S. van Wijnbergen, Trade reform, policy uncertainty, and the current account: A non-expected-utility approach, *American Economic Review*, vol. 82, no. 3, 1992, pp. 626 - 633.

- No. 110 M. Verbeek and Th. Nijman, Testing for selectivity bias in panel data models, *International Economic Review*, vol. 33, no. 3, 1992, pp. 681 - 703.
- No. 111 Th. Nijman and M. Verbeek, Nonresponse in panel data: The impact on estimates of a life cycle consumption function, *Journal of Applied Econometrics*, vol. 7, no. 3, 1992, pp. 243 - 257.
- No. 112 I. Bomze and E. van Damme, A dynamical characterization of evolutionarily stable states, *Annals of Operations Research*, vol. 37, 1992, pp. 229 - 244.
- No. 113 P.J. Deschamps, Expectations and intertemporal separability in an empirical model of consumption and investment under uncertainty, *Empirical Economics*, vol. 17, no. 3, 1992, pp. 419 - 450.
- No. 114 K. Kamiya and D. Talman, Simplicial algorithm for computing a core element in a balanced game, *Journal of the Operations Research*, vol. 34, no. 2, 1991, pp. 222 - 228.
- No. 115 G.W. Imbens, An efficient method of moments estimator for discrete choice models with choice-based sampling, *Econometrica*, vol. 60, no. 5, 1992, pp. 1187 - 1214.
- No. 116 P. Borm, On perfectness concepts for bimatrix games, *OR Spektrum*, vol. 14, no. 1, 1992, pp. 33 - 42.
- No. 117 A.P. Jurg, I. Garcia Jurado and P.E.M. Borm, On modifications of the concepts of perfect and proper equilibria, *OR Spektrum*, vol. 14, no. 2, 1992, pp. 85 - 90.
- No. 118 P. Borm, H. Keiding, R.P. McLean, S. Oortwijn and S. Tijs, The compromise value for NTU-games, *International Journal of Game Theory*, vol. 21, no. 2, 1992, pp. 175 - 189.
- No. 119 M. Maschler, J.A.M. Potters and S.H. Tijs, The general nucleolus and the reduced game property, *International Journal of Game Theory*, vol. 21, no. 1, 1992, pp. 85 - 106.
- No. 120 K. Wärneryd, Communication, correlation and symmetry in bargaining, *Economics Letters*, vol. 39, no. 3, 1992, pp. 295 - 300.
- No. 121 M.R. Baye, D. Kovenock and C.G. de Vries, It takes two to tango: equilibria in a model of sales, *Games and Economic Behavior*, vol. 4, no. 4, 1992, pp. 493 - 510.
- No. 122 M. Verbeek, Pseudo panel data, in L. Mátyás and P. Sevestre (eds.), *The Econometrics of Panel Data*, Dordrecht: Kluwer Academic Publishers, 1992, pp. 303 - 315.
- No. 123 S. van Wijnbergen, Intertemporal speculation, shortages and the political economy of price reform, *The Economic Journal*, vol. 102, no. 415, 1992, pp. 1395 - 1406.
- No. 124 M. Verbeek and Th. Nijman, Incomplete panels and selection bias, in L. Mátyás and P. Sevestre (eds.), *The Econometrics of Panel Data*, Dordrecht: Kluwer Academic Publishers, 1992, pp. 262 - 302.

- No. 125 J.J. Sijben, Monetary policy in a game-theoretic framework, *Jahrbücher für Nationalökonomie und Statistik*, vol. 210, no. 3/4, 1992, pp. 233 - 253.
- No. 126 H.A.A. Verbon and M.J.M. Verhoeven, Decision making on pension schemes under rational expectations, *Journal of Economics*, vol. 56, no. 1, 1992, pp. 71 - 97.
- No. 127 L. Zou, Ownership structure and efficiency: An incentive mechanism approach, *Journal of Comparative Economics*, vol. 16, no. 3, 1992, pp. 399 - 431.

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